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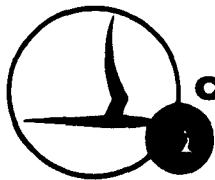
**PROJECT AWAS
ATTACK WARNING ACTION SELECTION
A WARNING DECISION STUDY**

Prepared for:
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Washington 25, D.C.

FINAL REPORT

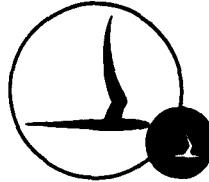
By: Norman P. Salz and Jaime F. Torres
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CORNELL AERONAUTICAL LABORATORY, INC.

OF CORNELL UNIVERSITY, BUFFALO 21, N. Y.



CORNELL AERONAUTICAL LABORATORY, INC.
BUFFALO 21, NEW YORK

PROJECT AWAS
STUDY OF
ATTACK WARNING-ACTION SELECTION

A WARNING DECISION STUDY

NORMAN P. SALZ
JAIME F. TORRES

CAL REPORT NO. VP-1698-G-1
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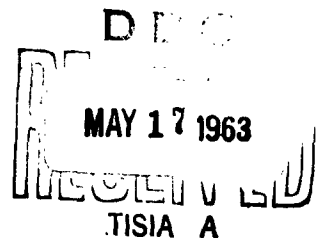
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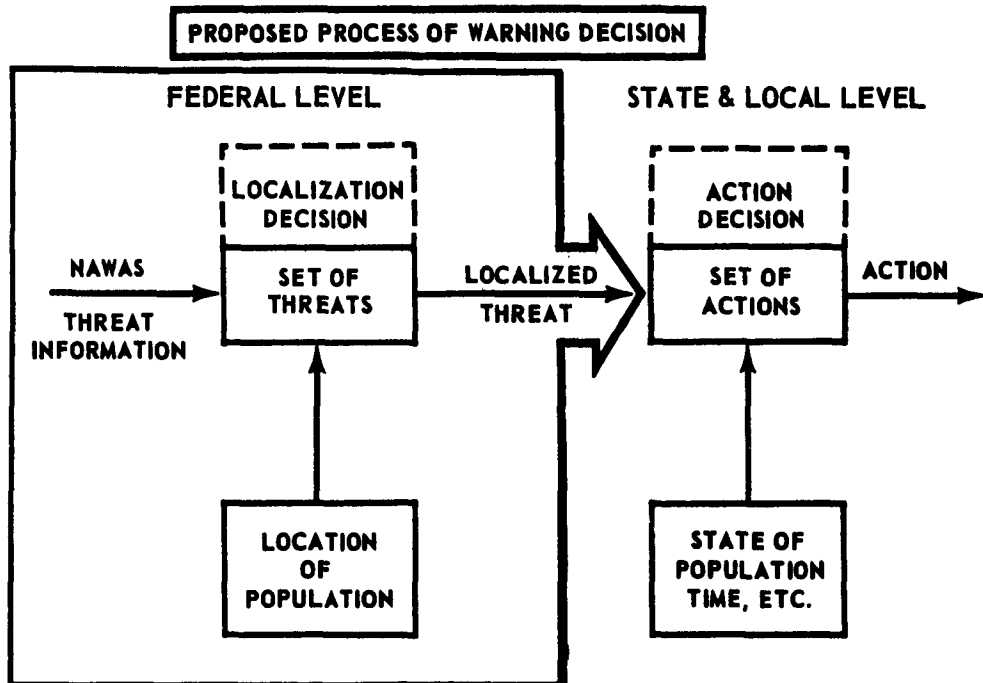
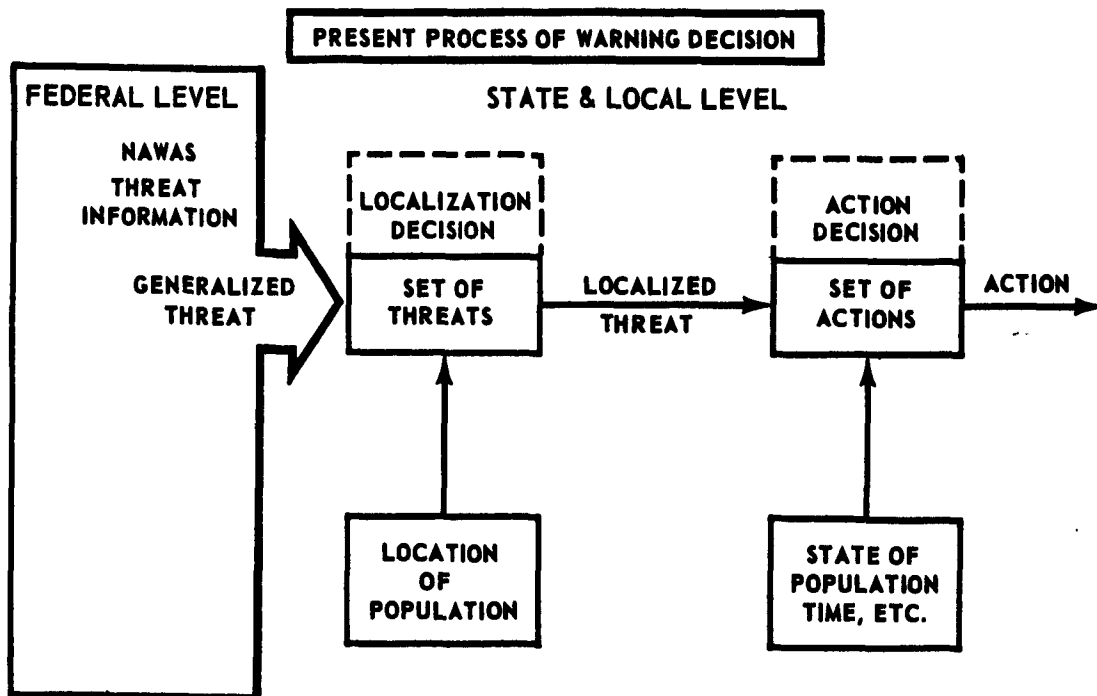


Figure 1 PRESENT AND PROPOSED WARNING DECISION PROCESS

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ABSTRACT

This is a report of a brief study of (Civil Defense) Attack Warning Dissemination and Action Selection (AWAS) performed by the Cornell Aeronautical Laboratory, Inc., for the Office of Civil Defense, Department of Defense, under Contract OCD-OS-62-138.

The procedures for the transmission of attack warning from NORAD through the states to local governments are well established and in daily use. An evaluation of these procedures and the development of improved methods to influence, expedite and activate decisions at the state and local level are the subjects of the present AWAS study.

The approach employed in this program is to study the Operational Survival Plans of a sampling of states and localities, to supplement the basic input data with conferences when deemed necessary, and from the available data to

1. analyze the characteristics of the present Warning Decision process
2. identify the problems of the Warning Decision process
3. determine the critical factors in the present Warning Decision process
4. recommend improvements in the Warning Decision process
5. recommend research required for suggested improvements
6. recommend required research for those problems which could not be adequately analyzed within the current program.

The principal result of the study is the determination that the major impediment to the activation of attack warnings at state and local levels is the present necessity for the state and local decision-makers to make a localization-decision, i. e., to define the threat to their locality of responsibility, before an action-decision can be made. It is recommended that this decision of localizing

the threat be made at Federal level. To further expedite action-decisions it is recommended that the informational-content of attack warning be mated through preplanning to the set of available actions at state and local level through the proper employment of Threat State warnings. The areas of study required to implement these recommendations are pointed out.

CONCLUSIONS AND RECOMMENDATIONS

Conclusion I The present form of NAWAS warning information serves to prevent the timely activation of decisions at state and local level. (This is the major conclusion of the study.)

Background A fundamental purpose of the National Warning System (NAWAS) is to provide timely information so that, under threat, decisions can be made at state and local levels which will be productive of an optimal set of life-conserving actions.

An examination and analysis of attack-warning procedures was followed by discussions with attack warning personnel, and the findings were as follows:

- Findings
1. Present-day warning decision is a two-stage process consisting of an attack localization decision and an action decision.
 2. The two-stage process places a severe burden on the state and local decision-makers and serves to prevent the timely influencing and activation of decisions at these levels.
 3. The localization decision had been developed empirically because of the form of the warning information being passed down by NAWAS to the states and localities.

These findings lead to the above conclusion and to the following recommendations.

Recommendations

1. The threat evaluation task of localizing a warning, i.e., the localization-decision, be removed from the lower echelon and borne by the Federal Government, and that
2. the action-decision be retained at state and local level;

3. the localized warnings be presented in a form permitting a more rapid response of an action-decision;
 - 3.1 the localized warnings be in terms of categories of threat, or Threat States, to each state and local area;
 - 3.2 the action-alternatives at local level be premated to the Threat States;
4. as an interim measure, OSP's be augmented by recommended procedures for warning decision; and that,
5. a research program be initiated to implement the goal of determining a set of Threat States which will minimize the expected losses of population.

Conclusion II The ordering in attack-warning dissemination is found to be unrelated to population survivability. (This is not as critical to the problem of present-day attack warning decision as Conclusion I, but is relevant and important.)

Background Decisions are expedited, per se, by a more ready access to pertinent and well-structured warning data.

A survey of present-day warning dissemination technique revealed that population reaction time, and in some instances, population itself, is not taken into consideration in determining the order in which population centers are warned.

Analysis The problem of the optimal sequencing of warning points was formulated and solved in terms of a population survivability function, which was developed to the purpose. An improved method was developed to the end that losses are minimized.

Recommended Research It is recommended that the loss (or survivability) function generated in this study be further studied to determine the functional form of the relationship and its variation with population, population density, available shelters, civil defense training, etc.

Conclusion III In situations where the opportunity for strategic warning exist, time is available to provide a high degree of protection for the civil population. The finding of the present study is that the expected performance is far from optimal.

Background The National Plan specifies that adequate provisions will be made to furnish the state and local political subdivisions with the appropriate strategic... information in order that they may in turn prescribe the appropriate actions to be taken. An examination made of state Operational Survival Procedures led to the following findings:

- Findings
1. Consideration is noted in almost all OSP's of the possibility of strategic warning.
 2. The form and character of the strategic information and inputs is not spelled out.
 3. The decision rules and criteria to determine action on the receipt of strategic information are nonexistent.

These findings lead to the above conclusion and to the following recommendations.

- Recommendations
1. A detailed study be made of the value of strategic warning information to population survivability within the context of its bearing on military and diplomatic policy,
 2. if deemed of value, that explicit procedures be developed for the transmission of strategic information to state and local level,
 3. and, further, that decision rules and criteria be developed for use at state and local level for the assimilation thereof.

PROJECT AUTHORITY AND CONTRACT SCOPE

The Contract OCD-OS-62-138 specifies the scope of the work to be performed in this study. The objective of the study is to develop and evaluate improved methods for influencing, expediting and activating attack warning decisions at the state and local levels. To be included in the study are such factors as chain of command, points of decision-making, timing, selective warning, the various routes available through designated personnel and the operational controls needed for the development and evaluation of improved methods. The extent to which NEAR may influence the warning process shall be included in the over-all evaluation as well as the effects of other possible warning methods. The specific tasks to be performed are:

1. Survey of Attack Warning Systems Environment

A survey should be made of the procedures used within the National Warning System, as well as those used at the state and local level.

2. Study of the Actions Involved by the Warning Process

Examine existing national, state and local operating instructions and procedures to determine the actions presently required to achieve the requisite civil defense of the region involved.

3. Analysis of Factors in Warning Decision-Making

Examine existing national, state and local standard operating instructions and procedures to determine the critical factors which are presently inherent in the warning decision-making process.

4. Evaluation of Existing Warning Decision

Select a typical warning dissemination and action selection chain that spans the national, state and local level.

5. Development of Improved Procedures

Develop and evaluate improved procedures for attack warning dissemination and action selection.

GUIDANCE

The study was directed by the sponsor to focus on state and local level to minimally overlap a companion study of Warning Requirements.*

EFFORT

The level of effort was one man-year. The contract was performed by two men over an interval of six months to permit the interchange of ideas and to provide OCD with more rapid access to the conclusions and recommendations of the study.

* OCD-OS-62-119, Systems Development Corporation

INTRODUCTION

The over-all Attack Warning System that serves as a background for the study is depicted in block diagram in Figure II. Initiating at the OCD Attack Warning Office at the NORAD Combat Operations Center, the system is designed to disseminate attack warnings on down to the general population. The National Warning System (NAWAS), which forms the Federal civil portion of the Attack Warning System, was established to transmit warning information to individual warning points within the states. As presently constituted, the Federal interstate attack warning responsibility terminates with the transmission and updating of attack warning information to these warning points.

The attack warning information is passed down from the Federal Government to the state and lower echelon warning points in the following form:

1. A clock is started at the time the initial warning is given. Subsequent information is given in terms of this (Zulu) time scale.
2. General location of aircraft and general launching sites of missiles, when known, are given.
3. Warning times are given relative to a subset of reference cities distributed throughout the United States, as shown in Figure III.
4. Each raid (manned aircraft) is tagged with a raid number; each missile launch, when possible, with a launch number.
5. The location of each raid* is transmitted, when known, utilizing GEOREF coordinates.
6. The course of each raid* is transmitted.
7. The speed of each raid* is transmitted.

* and missiles when known.

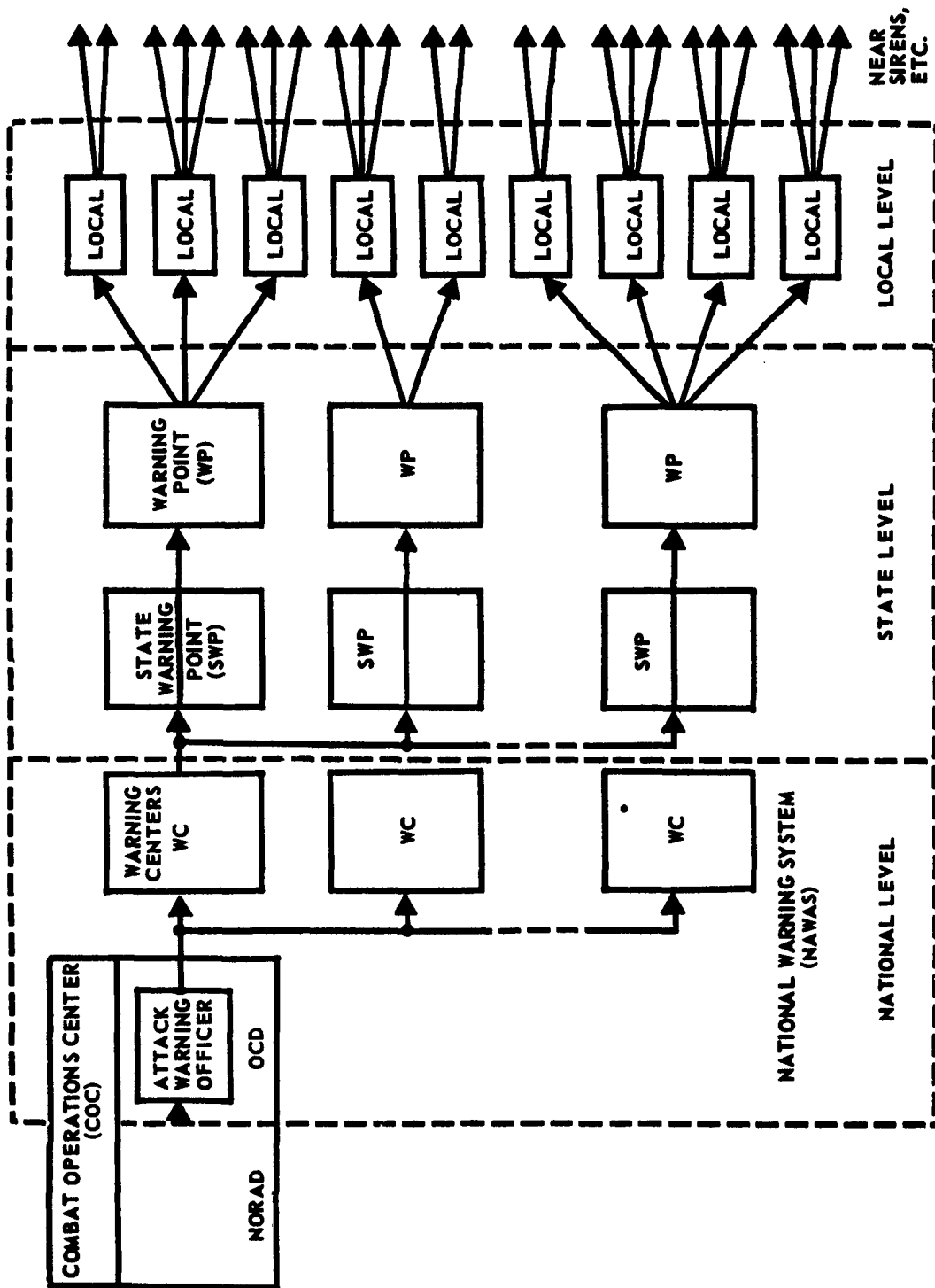


Figure II EXISTING ATTACK WARNING SYSTEM SCHEMATIC

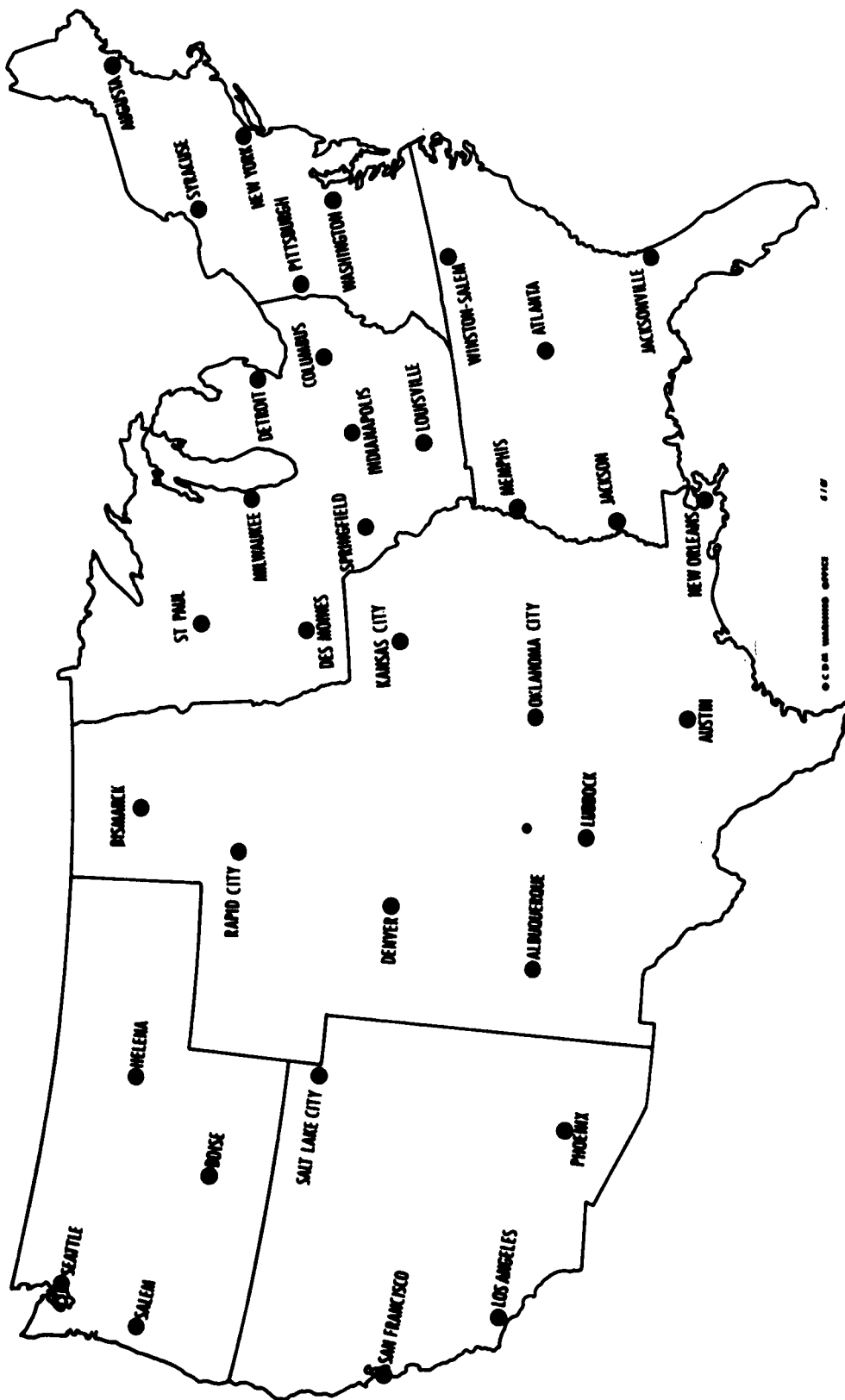


Figure III REFERENCE CITIES FOR WARNING TIME

8. The number in each raid *

9. The above is supplemented by occasional status reports relating to damage assessment.

The various state and local governments have assumed the responsibility of establishing and operating the required warning subsystems which link NAWAS warnings to the general public. Each state, in exercise of this intrastate responsibility, has formulated an Operational Survival Plan (OSP) which attempts to mesh with the NATIONAL PLAN. Generally the civil defense responsibility of the governor is delegated, sometimes co-delegated, to a state Civil Defense Director who works with local deputies. In order to ensure a 24-hour operational capability, most of the warning points are located at police or sheriff's headquarters. The operators on duty at these points are generally instructed to alert higher civil defense officialdom of the receipt of warning received over the NAWAS chain.

The major qualitative areas of interest to the present study are encompassed by the following questions:

What decisions presently exist within the warning structure?

Are these actually required?

What is the basis for present decision-making; in other words, what criteria are employed?

What criteria are required for effective warning decision-making?

Is an improved, or perhaps optimal, location of decision points possible?

What improvements in warning dissemination and warning decision methodology will more effectively influence, expedite, and activate warning decision at state and local level?

The AWAS study is a study of Warning Decision. The mechanics of physical implementation is touched upon but is not treated in detail. In such devices as broadcast radio, NEAR, etc., adequate scientific know-how is available to implement any attack-warning chain. The question of what it is we want to do points to the answer of how we best can do it. This report is addressed to providing an answer to the question. The task is so broad in concept and varied in detail that it is clearly necessary to limit the scope of the study program.

* and missiles when known

Scope: The States Studied

Each state as well as each political subdivision will issue its operating procedures to deal with the problem of attack warning dissemination-action selection. Differences in attack-warning procedures result from the differences in varied factors such as funding, geography, population density, target value, etc., that can exist among such political entities, in addition to purely subjective factors. An exhaustive evaluation of all warning dissemination-action selection procedures, throughout the whole nation, is quite evidently impractical. The present AWAS study is based on a sampling that included a study in depth of the warning decision procedures of three representative states and a somewhat less intense study of those of six others.

The factors taken into consideration in the choice of States were the population density, the relative centralization or decentralization of the procedures and the proximity to the investigators. On the basis of Table I, and the other considerations noted above, the procedures of the states of New Hampshire, Delaware and New York were selected for study in depth.

When a point had been reached in the AWAS study where certain preliminary conclusions were being suggested by the input data pertaining to these states, it was recommended that the results be tested against a somewhat larger sample of States. The procedures of Kentucky, Maryland, Ohio, Pennsylvania, Virginia and West Virginia (all in Region 2) were analyzed, but to a lesser degree.

Scope: Warning Phase

The study is concerned with the time period commencing with the initiation of a warning message from NORAD Headquarters or other warning center, and terminating with the receipt of warning by the lowest CD echelon in the attack warning chain, and/or the populace at large (whether or not, and to what extent, the public becomes involved is a decision within the chain). The time interval of the present study might reasonably be called the Warning Phase.

As depicted in Figure IV, preceding the Warning Phase there exists an interval of time that starts when the threat is first sensed and is concluded with the decision to transmit a warning over NAWAS. This period might be called the Prewarning Phase.

Table I
Ranking of States by Population Density
Basic Data: Bureau of Census

		State Density				State Density	
		State Density ¹	U. S. Density ²			State Density	U. S. Density
1.	New Jersey	800.2	15.9	26.	Alabama	63.5	1.26
2.	Rhode Island	798.7	15.8	27.	Missouri	61.8	1.23
3.	Massachusetts	650.1	12.9	28.	Iowa	48.8	0.968
4.	Connecticut	513.3	10.2	29.	Mississippi	45.8	0.909
5.	New York*	346.2	6.87	30.	Washington	42.4	0.841
6.	Maryland**	311.3	6.18	31.	Minnesota	42.4	0.841
7.	Pennsylvania**	249.3	4.95	32.	Vermont	41.7	0.827
8.	Ohio**	235.0	4.66	33.	Texas	36.2	0.718
9.	Delaware*	224.0	4.44	34.	Arkansas	33.8	0.671
10.	Illinois	179.0	3.55	35.	Oklahoma	33.4	0.663
11.	Michigan	136.4	2.71	36.	Maine	31.1	0.617
12.	Indiana	128.1	2.54	37.	Kansas	26.3	0.522
13.	California	99.2	1.97	38.	Oregon	18.3	0.363
14.	Virginia**	97.7	1.94	39.	Nebraska	18.3	0.363
15.	Hawaii	96.8	1.92	40.	Colorado	16.7	0.331
16.	North Carolina	92.2	1.83	41.	Arizona	11.3	9.224
17.	Florida	90.1	1.79	42.	Utah	10.8	0.214
18.	Tennessee	84.6	1.68	43.	North Dakota	9.0	0.179
19.	South Carolina	77.9	1.55	44.	South Dakota	8.9	0.177
20.	West Virginia**	76.7	1.52	45.	Idaho	8.0	0.159
21.	Kentucky**	75.6	1.50	46.	New Mexico	7.8	0.154
22.	Wisconsin	71.8	1.42	47.	Montana	4.6	0.0913
23.	Louisiana	71.6	1.42	48.	Wyoming	3.4	0.0675
24.	Georgia	67.2	1.33	49.	Nevada	2.6	0.9516
25.	New Hampshire*	66.5	1.32	50.	Alaska	0.4	0.00794

¹ per square mile of land area

² 50.4 people per square mile

* studied in depth

** peripherally studied

Following the Warning Phase there exists an interval of time, the Post warning Phase, which terminates at such time as the set of protective actions decided upon have been carried out or the attack has been aborted or completed.

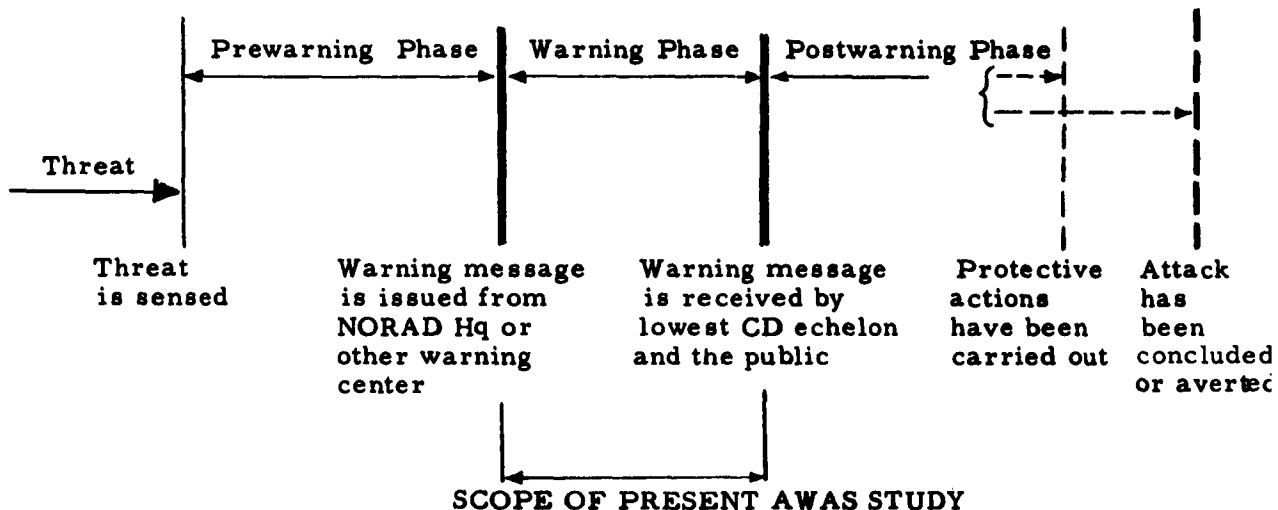


Figure IV

Table II illustrates the above phases and indicates the major decisions pertaining to each.

Following the receipt of warning a local decision must be made on what action should be implemented from the set of possible alternatives available at the time the warning is received.

The *raison d'être* of the entire attack-warning chain is to match a threat with optimal protective actions at local level. The recipients of warning at local level comprise the entire civil population of the United States, engaged in the myriad activities which comprise living. At any given time of day or night, some of the population are at work, some at home, some at play, some asleep, some with their families, and others in-transit to or from their residences, etc.

INTERVAL	START	FINISH	MAJOR DECISIONS
PREWARNING PHASE	Threat Sensed	Warning Sent from NORAD Hq.	Shall Warning be Sent?
WARNING PHASE	Warning Received from NORAD Hq.	Warning Sent to Lowest CD Echelon and the People	Wait? Selective Warning? Alert? Inform? Take Cover?
POST WARNING PHASE	Warning Received by Lowest CD Echelon and the People	Action by People or Attack Concluded, or both	Residential Decisions Industrial Decisions In-Transit Decisions

THE PHASES OF ATTACK WARNING DISSEMINATION

Table II

1.0 WARNING DECISION

A fundamental purpose of the National Warning System (NAWAS) is to provide timely information so that, under threat, decisions can be made at state and local levels which will be productive of an optimal set of life-conserving actions.

In this section, the process of warning decision is described. Present-day warning decision is depicted as a two-stage process, consisting of a localization-decision and an activation-decision. This is found to be necessitated by the form of the warning information passed down by NAWAS to the states and localities. It is indicated how this dual decision places a severe burden on the state and local decision-maker and serves to delay the timely influencing and activation of decisions.

Since decisions are expedited by a more ready access to pertinent and processed warning data, an analysis is undertaken of present-day warning dissemination technique. The order in which attack-warning is sent to warning points is found to be unrelated to population survivability. The problem is analyzed, a survivability function generated, and an improved method developed which serves to expedite the sequential communication of warning information to the end that losses will be minimized and survivability enhanced.

The problem of the form of the NAWAS information was adjudged to be the major limitation of the warning-decision process. An analysis provided recommendations for improvement.

1.1 Influencing and Activating Decisions

The following section analyzes the decisions that are made in the warning structure. Following the consideration and analysis of the elemental decision of stimulus-response, the warning decision is defined and studied. It is shown to be composed of two complementary decisions, a localization-decision and an action-decision.

1.1.1 The Warning Decision: A Two-Stage Process

In the warning decision situation the decision-maker, faced by a particular stimulus, must choose one action from a set of alternative actions. Although the common concept of the decision relates to this choice of action it will be shown that the warning-decision situation is in fact more complex, involving two complementary decisions: a localization decision and an action decision.

We shall develop the ideas in terms of the following example of a warning decision situation:

"If hostile vehicles are enroute but more than X minutes from location Y, then "Wait" or "Selectively Warn CD Personnel" or "Sound the Alert" or "Sound the Take Cover".

Tacit is the implication that in the absence of the stimulus of the presence of hostile vehicles there is no necessity to choose one of the alternatives. If the question "Are hostile vehicles enroute but more than X minutes from location Y?" has an affirmative answer, the decision-maker then chooses one of the alternatives; if, on the other hand, the answer is negative, he does not. In the presence of an unequivocal answer to the question (the stimulus); there is thus still a decision to be made about what to do (the response). The unequivocal presence of stimulus serves to trigger the decision-process. However to answer the question the decision-maker must interpret such data as available and which he deems relevant to the question and, in fact, determine whether or not the stimulus is present. This act introduces a subjective element into the situation.

The decision-maker may in error reject information that is provided as being indicative of the stimulus, when in reality the stimulus is present; and, conversely, he may in error accept information that is provided as being indicative of the stimulus, when in reality the stimulus is absent. The latter type of error (false alarm), while costly as regards public acceptance of the concept of civil defense, is not nearly as costly as the former type (erroneous delay) which represents a failure of the entire system. These errors of

interpretation may be introduced in two ways. The input information may be ambiguous. The decision-maker cannot interpret with certainty but knows (although not necessarily quantitatively) that the probability of the presence of the threat is of the order of 70%, say; and so the probability that the threat is absent is of the order of 30%. Hence if he responds with a decision that alerts the populace he falsely alarms 30% of the time; and if he does not respond he erroneously delays 70% of the time.* On the other hand, the input information may be unambiguous and the error is introduced by the subjective misinterpretation of the decision-maker.

The decision process is seen to be initiated upon the receipt of information that can be understood to be indicative of the presence of the stimulus. The presence or absence of such stimuli is a matter of interpretation of input data. In the presence of a correctly interpreted unambiguous stimulus, then, the decision-maker can choose one of the alternative courses of action; in the presence of an ambiguous stimulus, the decision-maker must first evaluate whether or not the stimulus is present, and, if one is deemed present, then decide on a course of action. On the acceptance of the fact that a stimulus exists, the decision-maker chooses that alternative which, in terms of the situation which confronts him, represents a preferred choice. In a given situation he chooses that alternative whose performance against a set of criteria has the greatest value to his goal. In civil defense, the goal is to minimize the loss of life. He chooses that alternative which in his judgment minimizes the losses.

In many situations, the actual determination of the presence or absence of the stimulus is a delicate operation involving the consideration of probabilities and the exercise of experienced judgment. The attack warning decision situation is no exception. This is a judgment of CINCNORAD made with the best intelligence estimate of the situation. No lower echelon in the attack warning chain is faced with the necessity or has the capability to exercise its judgment in these matters. Rather, the present system places the burden on the lower echelons of interpretation of the potential effect of the threat on them. The lower echelons, in other words, are presently required

*Which he chooses to do depends on his motivation. Does he lose his job if he falsely alarms?

to particularize, or localize, the threat: this is the first stage of the decision process. They are then required to choose a preferred action-alternative from a set of actions: this is the second stage.

1.1.2.1 First Stage: The Localization Decision

The decision to implement a warning with action is seen to be delayed by the prior necessity to interpret a general threat as a threat to a particular state and community: this is the Localization Decision.

The present procedures of attack warning provide relatively raw data through the NAWAS Warning Centers. These data reference the warning times of hostile air vehicles to certain reference cities as well as provide instant information as to raid number and type, and update information on the location, course, speed and number in each raid. This is sometimes followed by descriptive remarks relating to damage assessment ranging from a short phrase to a paragraph.

At State Warning Points, and at warning points, these input data are recorded, usually by hand, and in some instances on magnetic tape, and are entered on plotting boards. At each decision point in each state, the data must now be acknowledged and then extrapolated, assimilated, evaluated and interpreted as to its meanings as a particular threat to the respective locality of responsibility of each decision point.

The acknowledgment, recording, plotting, updating, extrapolation, assimilation and at least a crude evaluation and interpretation of the data are tasks which must be accomplished at any hour of day or night by the personnel who are on duty. These personnel, in turn, are generally instructed (i. e., given the added task) to bring more highly trained CD personnel and officialdom to bear on these problems. Following this step, the subsequent stage of the localization decision is performed in one of several fashions. In some instances, a responsible official makes a decision as to the nature of the threat; in others, a meeting is called between, perhaps, a Mayor and City Council; in others, the Governor and/or legislature make(s) the interpretation of threat and then makes it public and hence official.

1.1.2.2 Second Stage: The Action Decision

Once a threat to his area of responsibility is decided upon, the decision-maker must relate it to the set of possible actions he has generally preplanned to meet the threat: this is the action decision.

Following the foregoing series of acts relating to threat definition, attention is directed to the thoughts of actions, that is, to the task of making the critical action decision. The decision to be effectuated is selected from one of the available set of state and local (generally all or partially preplanned) actions, based on attack assumptions which vary from state to state. The action decision is a function of the threat, of course, but in addition depends on such variational factors as the time of day and season of the year. Moreover, the decision itself varies from community to community, at the same time and under the same threat, because of such objective differences as the state of the shelter program, the education and training of the respective populations, as well as geographic, economic, and many other factors, some being subjective.

Formally, the action decision is a rule for mapping the set of possible warning situations onto the set of possible actions. Stated differently, such a decision rule implies the establishment of a correspondence between the set of possible warning information inputs and the set of action outputs. As an example, assume that all attack warning situations are characterized in terms of warning time. One possible mapping is to sound the TAKE COVER whenever an attack warning is declared and the warning time is less than 15 minutes; sound the ALERT whenever the attack warning is declared and the warning time is greater than 15 minutes; and WAIT when the attack warning is not declared.

Even though the actions that are possible are relatively small in number, the number of possible warning situations are infinite in number - thus admitting an infinite number of possible warning decision rules.

Of course, not just any warning decision rule will do. What is required is to make apt warning decisions. It is desired to select the most appropriate action that will correspond to the given warning situation. Thus, proper warning decision rules are a requirement.

What constitutes appropriate decisions is then open to question. A criterion that might be employed can be to consider the consequence of each action for any given warning situation, i.e., what damage may be done by bombs, what human effort may be expended, what psychological damage may be incurred, etc., by taking each course of action in any given warning situation. The best decision is then represented by that action which minimizes the average of the consequences, taken over the possible states of nature.

There are of course other criteria that one might use as well as the above. In any case, a criterion of choice, or some principle of selection, must be specified.

1.1.2.3 Schematic Representation of Present Warning Decision

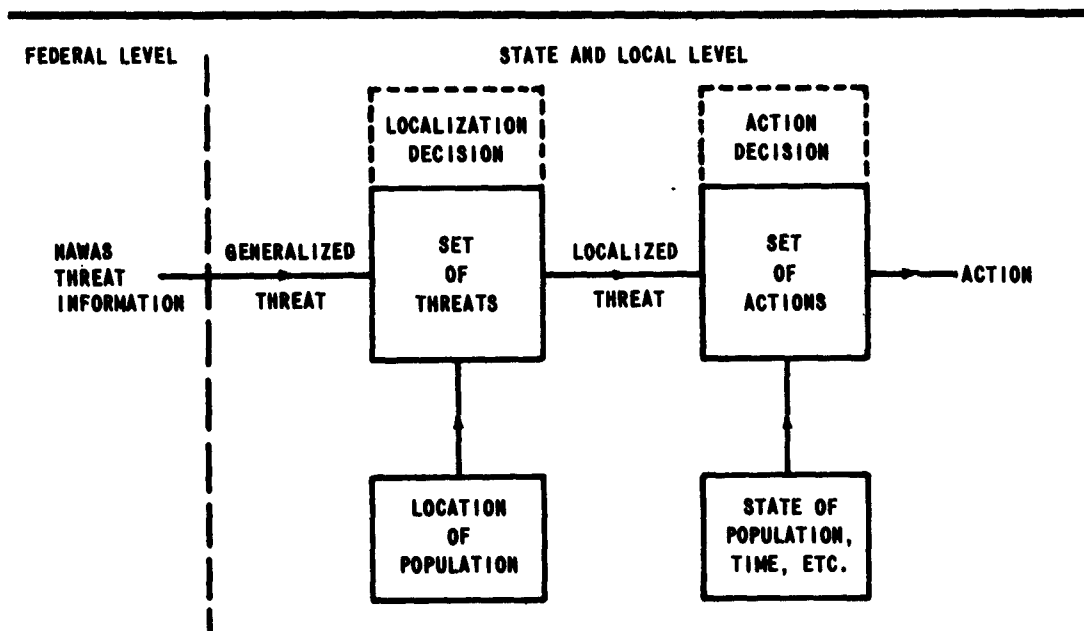


Figure V PRESENT PROCESS OF WARNING DECISION - A TWO STAGE PROCESS

As shown, the warning decision is bifacial, consisting of two complementary decisions, a localization-decision and an action-decision.

Localization Decision - The input information supplied by NAWAS is analyzed at state and local level and a determination is made that a threat does exist to the particular state or locality. This interpretation and localization is necessitated by the form of the input data.

Action Decision - If it is deemed that a threat does exist to a state or locality, the necessity arises to select a course of action.* To make this decision, the state of the population, available shelters, time, etc. are factors which enter the decision process. Most important, however, to the choice of action is the time available to perform the action.

The ultimate purpose of the attack warning system is to provide the general population with the time to implement the warning decision with protective action.

1.2 Expediting Warning Decisions

Since warning decisions are expedited by a more ready access to data, an analysis is undertaken of present-day warning dissemination technique. The sequence in which points are warned is found to be unrelated to survivability. The problem is analyzed, a survivability function generated and an improved method developed which will serve to expedite the sequential communication of warning information to the end that losses will be minimized and survivability enhanced.

The present procedures for the communication of attack warning information from NORAD through the states and to the lower CD echelons are well-established and in daily use.

The focus of this study is confined to the problem of expediting warning decisions at state and local level. It is evident that any method that permits the receipt by a state or locality of initial warning at the earliest time provides the greatest time in which to decide what to do, and to do it.

*Appendix I

Hence, the following discussion is devoted to the sequencing problem in the dissemination of warning information.

In considering the State of New York* the following situation is encountered: The NAWAS warning is immediately received by extensions into each of the 62 counties - but no knowledge of receipt of same is had at the State Control Point until after the warnings are acknowledged. In the event that no acknowledgment is received alternate means are employed to issue the warning. These alternate means are not employed until after the failure to acknowledge. The sequence of warning message acknowledgment determines the time of employment of alternate routes in the State of New York.

In the State of New Hampshire,** the warning is issued by a telephone fan-out network; viz., town A calls town B who calls town C while town A is calling town D, etc. An examination of the New Hampshire fan-out warning procedure suggested that an optimal sequence could be established. Thus, the question is raised:

Is there an optimal sequencing which, in context, provides minimum loss of life?

To make the result meaningful, the following parameters are introduced and subsequently developed:

A set of populations n_1, n_2, \dots, n_N ;

A set of respective weapon-times-of-arrival T_1, T_2, \dots, T_N ;

A set of respective loss functions $l_1(t), l_2(t), \dots, l_N(t)$.

The analysis described mathematically in Appendix III, first treats the lossless basis and then the loss basis problem. The solution developed provides a methodology for determining the optimal warning sequence.

Consider a set of N populations n_1, n_2, \dots, n_N , and that the time-of-arrival of the raid or missiles to each is respectively T_1, T_2, \dots, T_N . Assume that warning is sequential (e.g., New Hampshire) or the acknowledgment of receipt is sequential (e.g., New York). The time remaining after the receipt of the warning (acknowledgment) until the time-of-arrival of the weapon is the time in which to act. If acknowledgment of receipt-of-warning is not received

* See Appendix I

from the i^{th} population n_i , an alternate warning route is resorted to; perhaps, the same route is employed. The earlier in the sequence of warnings that a particular locality appears, the sooner is the warning acknowledgment received and the more time remaining in which to act.

The lossless problem is posed as follows: In which sequence shall warnings be given and/or acknowledgments of warnings accepted to provide the maximum (mean) time in which to act? The conclusion reached is that in any sequential warning to, or acknowledgment by, a set of populations the maximum mean time in which to act - or equivalently - the minimum mean warning time - is obtained by warning the point of greatest population first; the next highest population point second; etc.

The above solution is independent of the times-of-arrival of the raid or missiles, because there is no penalty, or loss, associated with having less time in which to act. These considerations led to the further generalization where the problem is formulated on a loss basis as follows:

Following the receipt of warning, a population associated with a warning point tends to survive: if the warning is received sufficiently early, the time to act is adequate to provide minimum losses; if the warning is received late (i. e., after the weapon has detonated), maximum losses are sustained; if the warning is received at a time between the above times, then a loss somewhere between minimum and maximum is suffered. The loss function is thus nondecreasing with time, commencing its transition from $\min(n_i)^*$ at a critical time, T_{ci} , and building up to $\max(n_i)$ at time-of-arrival T_i , as shown in Figure VI.

* There will be unavoidable losses due to warning brought on by heart-attack, etc.

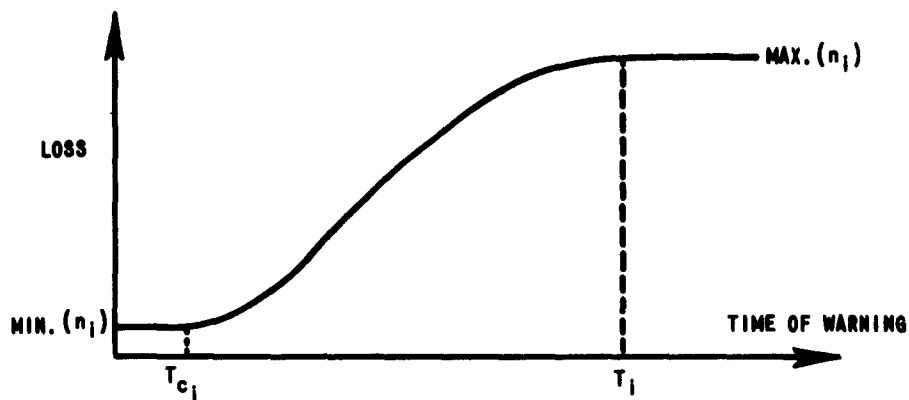


Figure VI LOSS AS A FUNCTION OF TIME OF WARNING

The above led to the formulation of the problem; Given a set of populations n_1, n_2, \dots, n_N , with respective weapon times-of-arrival T_1, T_2, \dots, T_N ; and respective loss functions $l_1(t), l_2(t), \dots, l_N(t)$,

How should the warning be sequenced to provide minimum loss (of life)?

On the assumption that warning to population n_i could be accomplished in the same time interval as warning to population n_j , $i, j = 1, 2, 3, \dots, N$, the problem is solved and described in Appendix III-B. On the assumption that warning of population n_i occurs in time t_i and n_j occurs in time t_j the problem is solved in principle in the sense that the problem is formulated and can be solved by enumerative procedures.

In an extension of the result the telephone fan-out network, or cascade, is considered and optimized. The mathematical procedures which allow for solution are described in Appendix III-C.

1.2.1 Further Comments on Sequencing Losses

In the sequencing context, the loss in present-day attack warning may be expressed as

$$\text{Present Loss} = \text{Minimal Loss} + \text{Malsequencing Loss}$$

where the minimal loss is obtained when the warning points are optimally sequenced, and the malsequencing loss is introduced by a present-day departure from the optimal sequence.

Through optimal sequencing, thus, the present loss is reduced to the minimum by the elimination of the malsequencing loss.

The minimal loss itself may be reduced by adding such improvements as shelters, further education and training (i.e., improved CD discipline), alerting devices such as NEAR to provide increased coverage, and the like. However, if the situation is changed, the sequencing must also be changed to provide the optimum.

For example, adding 500 conveniently placed shelters in the City of Rochester has two (possible) effects; namely, to provide a readier access to shelter for, say, x people, and also, perhaps, to change the position of Rochester in the warning/acknowledgment sequence--and thereby contribute further to the lowering of loss.

1.3 Major Limitation

The major limitation of the present attack warning decision process is the heavy burden that is placed on the decision-maker in being faced in time of crisis, when speed is of the essence, with the dual problem of a threat-localization decision and an action-selection decision. The responsibility in attack warning as a prime information source is that of the Federal Government. The form in which present information is passed down the chain is the underlying cause of the burden on the decision-maker.

Historically the states depend for their individual defenses on the Federal government. The states relinquish to it their fundamental prerogatives of self-defense in the certainty that in protecting all the citizens of the United States the citizenry of each state is protected. In the present world, a state does not exist per se as a target of a foreign power, for the foreign power recognizes that to attack any state of the United States is to attack the United States itself. Each state exists as a potential target only in the sense that it is part of the United States.

In the context of Civil Defense, none of the states is capable of interpreting a threat to the United States. None has equipped itself, none could equip itself, with the facilities and personnel to accomplish this task. Hence the states are presented with the necessity of defending their citizens against the enemies of the United States within the severe constraint of being dependent on the United States for prime informational inputs. The information is passed down with the main purpose of permitting the initiation of a set of protective action. However, the information is in such form that in lieu of the intended action-decision only a localization-decision is triggered. The general threat information that is passed down by NAWAS must first be evaluated and interpreted as a local threat.

The time consumed in making the localization-decision is time that could have been spent in implementing an action-decision. In periods of crisis, any reduction in the time to implement protective actions serves to defeat the purpose of the attack warning system. The decision-maker originally preplanned a set of actions based on his own assumptions, * varying from state to state, as to what the threat might be. The NAWAS input data, however, is received in such form that it must first be interpreted by him as a localized threat. The act of interpretation of threat is a weighty, difficult and time-consuming process. He must relate what he perceives to what he believes. His personal fortunes may sway his judgment. ** He is performing in an atmosphere of grave crisis.

* with Regional guidance

** If he guesses wrong and erroneously delays, who will (be left to) blame him; If he guesses wrong and falsely alarms, he may become the scapegoat...

The receipt of threat information thus leaves the local threat itself an open question, a matter of interpretation, a subject, perhaps for deliberation and discussion. The decision-maker is not presented with a single stimulus-multiple response situation: his first problem is to determine the stimulus. In some instances, as has been pointed out, a meeting is called to make the determination; in such cases, the delay introduced defeats the major purpose of the warning system. Moreover, in many instances the decision-maker is represented by such subordinates on duty as funding and time-of-day of warning permits. In these cases, a first evaluation, actually the localization of the threat, is made by personnel who may be ill-equipped by funding, training and preplanning to make such a determination.

Of the many limitations inherent in the present warning process* in its effect on expediting, influencing and activating decisions at state and local level the present study concludes that the major deficiency in warning decision is the heavy burden that is ultimately placed on the decision-maker.

* see Section 2.0

1.4 Recommendations for Improvement

The recommendations presented below represent an attempt to reduce the decision-points in attack warning to unambiguous stimulus - response points such that a preplanned action is an immediate response to a Threat State stimulus. The reduction is accomplished by the Federal warning level evaluating the threat and providing an unambiguous stimulus of Threat State to the warned level; the latter, having preplanned a suitable action to meet each condition of Threat State, is prepared to meet the threat with action.

1) The threat-evaluation burden of localization-decision should be removed from the state and local decision-makers and borne by the Federal Government.

The Federal Government alone can develop the capabilities, the facilities, personnel and funding required to determine the state of threat to each target.* Attack warning information should not be transmitted in raw form to the lower echelons which are generally ill-equipped to handle the responsibility. Passing this responsibility from Federal to local level does not expedite, activate or influence action. On the contrary, vital decisions are delayed by the red tape introduced when state and local governments are confronted by a localization-decision which time and available facilities do not suit them to make.

In recommending that information not be sent in raw form, it is suggested that information be sent in a form that is immediately useable by the recipient. The state or locality should, at the moment of receipt of warning, be apprised of the best threat estimate and so be in the optimal position to act immediately on the situation. The warning stimulus should trigger a response to the threat and not a response about the threat.

* The targets themselves are well-known and described in the National Plan (see Appendix I).

The reaction of an individual to the warning: "There is a fire in the house" is quite different from his reaction to the warning: "There is a fire in the neighborhood." In the first instance, he moves^{*} into action and in the second he asks "Where? (Is it a threat to my house?)" If he is told where the fire is, he would also have initially turned his thoughts toward action.

It is required that a decision be made at Federal level as to the relevancy or irrelevancy of the information passed down. Only attack warning information that has a bearing or which is deemed to have a bearing on future action should be sent. The fact that New York City is under attack is not required information in Los Angeles; yet it would be obviously advisable to notify Los Angeles that the country is under attack.

There is a great inducement to pass on every scrap of information and thus be confronted by no responsibilities of judgment. However, if the information serves no purpose except to enlarge the area of panic, it defeats the purpose of attack warning; namely, to set into motion the machinery of protective actions.

2) The action-decision should be retained at state and local level. The implementation should be expedited by premating the set of available actions to the set of Federal localized-threat warnings.

On the assumption that the Federal Government performs the function of providing localized and unambiguous threat information to each target area, it is evident that the decision requirement on the state and local level is reduced from the two-stage process discussed above to the sole necessity to provide an action from a preplanned set of actions to meet the threat.

*

In general, people do not accept warning or any surprise without verification.

Having removed the threat evaluation function from the state and local decision-maker, is it now possible to further reduce the problem of decision towards one of stimulus-response?

It has been noted that each state presently plans its set of actions based on its own assumptions pertaining to the threat. It then must dovetail its own concept of threat with its interpretation of the reality of the reported threat so as to choose an action it deems appropriate.

On the other hand, the decision is reduced to stimulus-response when action is based on a reported localized unambiguous threat to which a particular action had been premated.

3) The localized threat information passed down by the Federal level should be in a form permissive of an immediately triggering of an action-decision.* It is recommended that this information be in terms of the state of threat, or Threat States, to each state and local area.

An example of the form that the categories of threat, or Threat States, might take is described below. The nature of the research required to produce an effective set of Threat States is discussed in Section 3.0, Recommended Research.

*

In general there will be human override; however, this will relate to exceptions to preplanning.

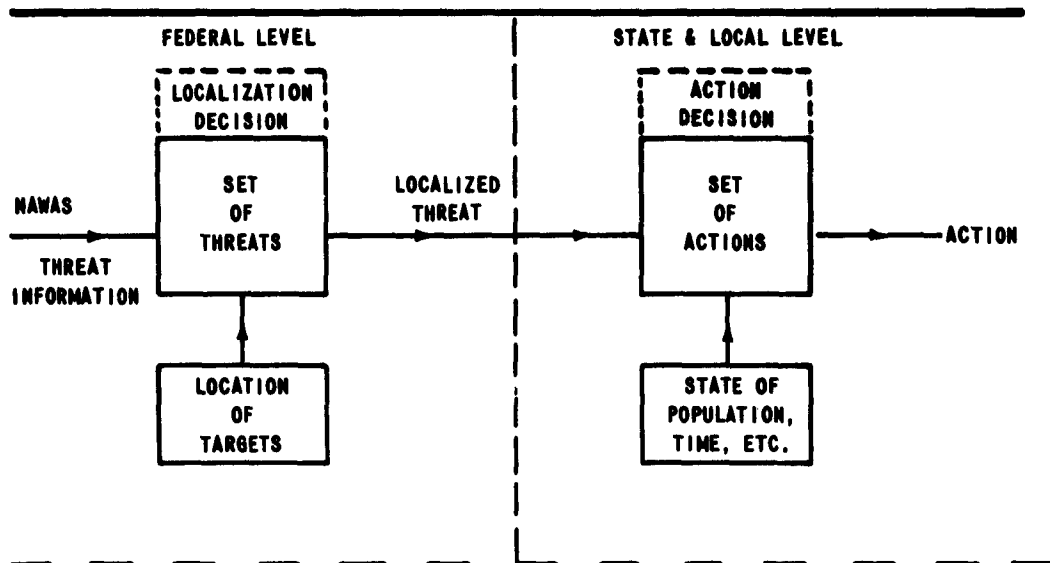


Figure VII RECOMMENDED PROCESS OF WARNING DECISION

The recommended warning decision process is depicted in Figure VII. As shown, the localization decision function is removed from the state and local decision-makers and transferred to the Federal level.

1.4.1 Example of Recommended Warning Decision Procedures

The premating of warning and action is presented through an example which incorporates the recommended procedures. Assume that the threat is effectively predefined* by the Federal Government in terms of threat categories, or Threat States, as shown in Table III.

* It is not within the scope of the present study to attempt to define the effective set of states of threat, but to the point to the advantage of threat definition to the decision process. The actual number of categories is itself a subject for research. (See Section 3.0 Recommended Research.)

Symbol	Threat State	Time to Go
T ₁ , Red	Threat State 1	0-1/2 hour
T ₂ , White	Threat State 2	1/2 hour - 1 hour
T ₃ , Blue	Threat State 3	1 hour - 4 hours
T ₄ , Orange	Threat State 4	4 hours - 24 hours
T ₅ , Yellow	Threat State 5	More than 1 day

THREAT CATEGORIZATION

TABLE III

It is seen that threat symbols are assigned to threats based on their time-of-arrival to a particular locale; for example, Threat State 2 or T₂, symbolized by a white color, means that the threat is one-half hour to one hour from localities under this state of threat. The Threat State, of course, varies with time and from community to community. For example, at a particular time, Nashua, New Hampshire might be in Threat State 2, while due to the same raid, Erie, Pennsylvania might be in Threat State 3.

Now let it be assumed that Threat State information is the only attack warning information that is supplied to the states by the Federal Government.

If this is so, it would place on the states and localities the necessity to preplan* what to do in the event of the occurrence of each of the states of threat. In relating to the physical location of the population, the choice of action is dependent on the time of day, of week and of year, the weather, etc. Assuming that each action is preplanned, it follows that the Threat State warning information supplied results in an unambiguous stimulus-response situation.

*Nor is it in the scope of this study to delineate the categories of state and local action vis à vis threats, but to point out the advantages to the decision process, and to propose (see Recommended Research) a method to accomplish this goal.

Stimulus: Threat State	RESPONSE: ACTIONS		
	Days		Nights
	Weekdays	Weekends & Holidays	
T ₁	a ₁₁	a ₁₂	a ₁₃
T ₂	a ₂₁	a ₂₂	a ₂₃
T ₃	a ₃₁	a ₃₂	a ₃₃
T ₄	a ₄₁	a ₄₂	a ₄₃
T ₅	a ₅₁	a ₅₂	a ₅₃

MATRIX OF PREPLANNED ACTIONS MATCHED
TO EACH THREAT CATEGORY

TABLE IV

As shown in Table IV the response to the Threat State warning is one action of a set of possible actions which is responsive to the time of occurrence of the warning. If T₂, for example, occurs on weekdays we respond with action a₂₁; on the other hand, if T₂ occurs on a weekend, we respond with action a₂₂.

For the illustrative case, we may define **

Day - time interval from 0700 to 1900

Night - time interval from 1900 to 0700

Weekday - Monday, Tuesday, Wednesday, Thursday, Friday

Weekend - Saturday, Sunday

Holidays* - Jan.1, Feb. 22, May 30, July 4, September 3, November 11,
November 22, December 25, 1962

*Note that holidays vary from state to state as to date and manner of observance.

** The matrix presented does not purport to include all factors but is shown for illustrative purposes only.

There is seen to be no choices left since all the possibilities are enumerated: a complex decision situation has been converted, by preplanning, into a stimulus-response situation.

Although the description and choice of action are seen to be predecided to best match the state of threat, the implementation (and possible modification of the detailed contents) of this decision with action is of necessity done under human direction.* What to do is known, how to do it will in fact vary with prevalent radioactivity, road conditions, weather, season of the year, etc. Hence, the implementation of the contemplated preplanned actions would be subject to human override.

The entire attack-warning decision-process is reduced to stimulus-response with human-override.

1.4.2 Set of Tasks at Each Level Required to Implement Recommended Improved Procedures

The implementation of the improved procedures sets certain tasks at the various levels of government. These are presented below:

Federal:	Predefine m states of threat
	Recommend a set of actions to correspond to each state of threat
	Evaluate and interpret the data as a state of threat to each of the targets
	Communicate to each target area, and/or appropriate subdivision, its respective state of threat.
State:	Implement the preplanning of the recommended optimal set of local actions to meet each category of threat
	Direct action and provide localities with pertinent information that assists implementation when the threat exists

*To prevent, for example, the population exeuating via a route which is in an impassable state.

Local: Preplan with state supervision a set of actions to meet
 each state of threat

 Implement these plans with action, with human over-
 ride, when the Threat State exists

The first two functions to be performed at Federal level are

 To predefine m states of threat

 To recommend a set of actions to correspond to
 each state of threat.

 The implementation of these functions is discussed in the section on
Recommended Research (Section 3.0).

2.0 ENVIRONMENT OF WARNING DECISION

The following discussion of the environment of warning decision provides the basis for the foregoing analysis of warning decision. Further supporting data is included in Appendix I - Attack Warning Environment, and in the referenced bibliography.

In Sections 2.1 - 2.2, the Civil Defense mission and its relationship to warning capability are described. Warning is defined; the structure of a warning process is given; and the relevant attack warning requirements are outlined. The directives relevant to the establishment of decision-procedures are noted. The responsibilities of state and local government are specified. The fact that the OCD role is not limited but broadened by the intent of Congress is documented. In Section 2.3, the present implementation of warning decision procedures is described. In Section 2.4, the general command structure in state and local attack warning decision making is outlined, the categories of personnel involved, and their interrelationships. In Section 2.5, it is pointed out that although strategic and tactical warning are provided for in the National Plan that only the tactical warning is presently structured in the Attack Warning System. In Section 2.6, the present warning decisions are generically classified. In Section 2.7, the limitations of outdoor warning devices and some of the pros and cons of NEAR are discussed. In Section 2.8 the salient limitations of existing warning decision procedures are detailed.

2.1 Definition of Warning Capability

Warning is defined^{*} to be "the alerting of people to the threat of extraordinary danger and the related effects of danger. This includes the collection, evaluation, and dissemination of warning information by governments and the facilities needed to achieve this." Warning may be further detailed to be signalling to attract attention, and the simultaneous or subsequent description of the danger as well as the appropriate actions to be taken by the receiving party.

It is noted that there are two types of warning which the United States might have concerning an enemy attack; namely, strategic warning, based on evidence of enemy intentions to launch an attack against the United States, and tactical warning, based on knowledge of probable attack after it has been launched. However, attack may come without either strategic or tactical warning: the detonation of the first enemy weapon could serve as the basis for warning for the entire country. A warning process can thus be structured^{**} into the following categories: the perception of the threat; the transmission of signals to individuals, groups or organizations about the threat, and about what behavior will avoid it or reduce its hazards; the receipt and acknowledgment of the signal; the interpretation of the signal; and finally, execution of appropriate actions.

It is clear that an adequate attack warning capability requires that there be available

- 2.1.1 Strategic and tactical information gathering and processing media
- 2.1.2 Attack-warning dissemination network
- 2.1.3 Appropriate action selection structure and procedures.

* Reference (1), Annex 13

** Reference (14)

2.1.1 Strategic and Tactical Information Gathering and Processing Media

The National Plan^{*} specifies that adequate provisions will be made to furnish the state and local political subdivisions with the appropriate strategic and tactical information that is required in order that they in turn may prescribe the appropriate actions to be taken.

The Office of Civil Defense of the Department of Defense is directed to provide warnings and warning information to all states and, in accordance with Federal-State arrangements, directly to political subdivisions on the National Warning System (NAWAS). The Office of Civil Defense is prepared to provide such warnings and warning information by maintaining Warning Centers at NORAD Headquarters and other NORAD installations as are necessary to obtain such information.

Much of the information available at these NORAD Warning Centers will be of a tactical nature. The tactical information is obtained by electronic or mechanical means.

Strategic information is to be provided by appropriate Federal Agencies^{**} which are directed to provide the Office of Civil Defense with any information pertinent to strategic warning. This would take the form of maintaining up-to-date estimates on the capabilities of potential attackers and their probable intentions regarding attack on the United States.

2.1.2 Attack Warning Dissemination Network

The Attack Warning System^{***} has been established to disseminate the warning information from the Federal warning information sources through NORAD Headquarters to the warning information users, i. e., the state and local decision makers. The National Warning System (NAWAS) constitutes the Federal portion of the Attack Warning System.

^{*} Reference (1)

^{**} Reference (1) Annex 13, P. 7, describes the function to be performed but does not specify the Agencies involved.

^{***} For a detailed description, see Appendix I.

2. 1. 3 Action Selection Structure and Procedures

The states and local political subdivisions are organized* for civil defense as prescribed by the laws and regulations of the state and local government. The State Civil Defense Director, or his equivalent, directs and coordinates civil defense activities of the state, and is responsible to the Governor. The local Civil Defense Director directs and coordinates for his respective executive head, the civil defense activities of the political subdivision. These executive head levels and the corresponding Civil Defense Directors constitute the command echelons responsible for performing warning decisions - these are the attack warning decision-making levels.

To assist these command echelons, warning decision procedures are set up in the various states to implement, in principle, the activation of warning. The National Plan states that, on the basis of information handed down from the federal level, the decision makers at state and local level determine the appropriate action to take.

More specifically, it is stated that procedures will be established and tested at all levels for the dissemination of all types of warning received through the Attack Warning System, and that criteria and procedures will be established for the sounding of the ALERT and the TAKE COVER signals.

Further, the state and local governments are responsible for prescribing the action to be taken by the respective government and the public upon receipt of warning. The actions prescribed depend on the warning time available, and the conditions that exist at the time. Among the possible actions that may be taken are: evacuation or dispersal of target cities and other areas near assumed targets, if time and conditions permit;

*loc. cit., Annex 13

if time and conditions do not permit evacuation, full advantage will be taken of existing shelter and fallout protection will be improvised.

The National Plan strongly notes that the action to be taken is a local decision, predicated upon standing operating procedures in state and local plans and mutual-aid agreements.

2.2 Responsibility of the Office of Civil Defense

The OCD is not limited by statute to the role of passive observer; rather, it has been charged by Congress to exert active leadership in civil defense in providing direction, coordination and guidance to civil defense efforts at state and local level.

The following is excerpted from Public Law 85-606, 85th Congress, H.R. 7576, August 8, 1958, Sec. 2:

"It is the sense of the Congress that the defense of the U.S., in this thermonuclear age, can best be accomplished by enacting into law the measures set forth in this act. It is the policy and intent of Congress to provide a system of civil defense for the protection of life and property in the U.S. from attack. It is further declared to be the policy and intent of the Congress that the responsibility for civil defense shall be vested jointly in the Federal Government and the several states and their political subdivisions. The Federal Government shall provide necessary direction, coordination, and guidance; shall be responsible for the operation of the Federal Civil Defense Administration as set forth in this Act; and shall provide necessary assistance as herein authorized."

2.3 Implementation of Warning Decision Procedures

The warning decision procedures are methods and techniques to determine which actions and operations should be executed in the face of an attack warning situation. Seldom present in Operational Survival Plans are the criteria on which decisions are to be based, and the decision-rules to be employed. The sole exception to this is the sounding of the TAKE COVER.

The objective of effective warning decision procedures is to permit the optimal preservation of life and property. Prior to and upon the initiation of hostilities, significant efforts must be implemented to preserve the general population and the industrial capability of the country. To satisfy the objective, it is necessary to develop and employ criteria and decision-rules that provide the choice of an optimal set of actions and operations to meet the warning situation in terms of minimizing the negative consequences, or losses, in each situation.

The preceding sections have indicated the form of the recommendation to the state and local communities to adopt warning decision procedures. Such procedures are, in effect, methods and techniques to initiate and execute a sequence of actions or operations, given an attack warning situation.

To satisfy the National Plan, some states and local communities have attempted to more or less incorporate warning decision procedures into their Operational Survival Plans. In most instances these occur implicitly rather than explicitly. In general the criteria for decision-making, except in the instance of the sounding of the Take-Cover, have been found to be completely undefined and the decision-rules generally nonexistent.

In the absence of a procedure, it is required that an extemporaneous judgment be made by the state and local decision-maker or operator. Much depends on his particular background of training and experience as well as his innate qualifications for the task-at-hand. Under these circumstances, the judgments varies from individual to individual and is biased from the optimum by subjective factors.

The implementation of OSP's with operational warning decision procedures appears to be a definite requirement in order to maximize the expected survivability of life and property.

2.4 Attack Warning Decision Structure

In general, the attack warning decision structure in the various states consists of the following command echelons:

- 1) State Director
- 2) Area (sub-state) Directors
- 3) Local (city or county) Directors

The State Director of Civil Defense constitutes the highest state level of Civil Defense command. Area Directors of Civil Defense have been established in some states to expedite decisions and to provide assistance to the State Director. The local directors are, at least in principle, most accurately aware of the immediate warning requirements of their respective local region.

It should also be observed that the level of State Director is the point of contact between the levels of the local political subdivisions and the Federal Government.

On the basis of the warning information provided to the states and local communities by the Federal Government, the respective Directors of Civil Defense prescribe the appropriate courses of action that must be taken that most properly correspond to the warning situation. The prescription of courses of action may take the form of instructions or orders from the Civil Defense Directors.

The character and type of the instructions and orders depend on who the recipients of such information are, as well as on the warning situation. Civil defense warning decision procedures in Operational Survival Plans recognize three main categories of recipients of instructions and orders:

- 1) The public
- 2) Civil defense personnel
- 3) Government officials

However, it should be clear that even though there exist such categories of civil defense warning instructions and orders, the objective of providing attack warning is the preservation of life and property. Thus, in the final analysis, it is the general public that must be served, who must be provided with timely and appropriate warning. The alerting of civil defense personnel is, in fact, intended to serve such a purpose. Of course, civil defense personnel, with their specialized training, promote the ultimate objective. The alerting of government officials is intended for the execution of plans which will assure the survival of an integrated and organized social and economic order.

2.5 Warning

It is observed in the foregoing discussion that the National Plan provides for tactical and strategic warning. However, a study of some of the State Operational Survival Plans and Federal Warning Documents, as well as discussions with personnel associated with the attack warning problem, reveals that, in effect, the Attack Warning System at present only considers tactical warning information.

This is also evident upon the examination of the Air Raid Warning Information Form 227. The form specifically calls for raid locations and speeds, clearly implying tactical warning information.

Furthermore, personnel at the OCD Warning Centers noted that there are no provisions for disseminating strategic warning from these points through NAWAS. Personnel at some of the OCD Regional Headquarters pointed out that they are not aware of any strategic warning dissemination capability in the Attack Warning System. Possibly the only exception to this is the Washington, D. C. area where, it appears, provisions are made to disseminate this type of warning.

As a consequence of this concentration of attention on tactical warning, the warning decision procedures extant in the states and local communities are more specific and precise than procedures for strategic warning.

2.5.1 Tactical Warning

The TAKE-COVER is precisely, but not uniformly, structured; the ALERT, admitting a more general type of civil defense action, requires the issuance of follow-on instructions.

Possibly the best example of a precise tactical warning procedure is that which prescribes the TAKE-COVER condition. Most of the states have specified in their Operational Survival Plans that the TAKE-COVER signal

be sounded when the warning time gets below a certain level. This criterion is almost generally prescribed, but is not uniform. There does exist variability in the magnitude of the level from state to state, and even from one local community to another. The minimum TAKE-COVER warning criterion that has been observed is the 15 minute criterion. On the other hand, in some places it may be as high as one hour.

Many of the states allow the local Directors to determine when the TAKE-COVER should be sounded. This concession, presumably, implements some sort of selective warning for that warning condition. On the other hand, it appears that the ALERT is usually directed to be sounded at the State Director's level, although it is sometimes directed to be sounded at the Area Director's level.

The action to be taken, upon the sounding of the TAKE-COVER signal, of course, is quite specific and well defined - to immediately seek the best shelter available.

The ALERT signal admits a more general type of civil defense action than the TAKE-COVER. The sounding of the ALERT signal signifies that the public should turn on their radios and listen for instructions or orders. The sounding of the ALERT signal is followed by the issuance of instructions, such as:

- 1) Dispersal of manpower and equipment
- 2) Go home movement
- 3) Evacuation according to plans
 - 3.1) Limited
 - 3.2) General
- 4) Warn of radioactive fallout
- 5) Other civil defense actions
- 6) Announce an ALL CLEAR .

The specific set of actions considered depends on the state and local political subdivision.

2.5.2 Strategic Warning

The survivability of major populations is enhanced through the employment of strategic warning. However, explicit procedures for handing down processed and graduated strategic information through NAWAS are seldom present. The Operational Survival Plans are sometimes structured for a few strategic situations; but no decision rules or criteria are provided to relate the assumed situation to the entire spectrum of possible strategic situations.

Almost all State Operational Survival Plans explicitly consider the possibility of strategic warning. Certainly the National Plan notes that consideration should be given to the possibility of strategic warning* as well as tactical warning. However, in almost all of these State Operational Survival Plans, the decision structure and criteria to determine the appropriate action to take upon the receipt of strategic warning information are nonexistent.

There is considerable variability between the states in which the decision structure for strategic warning is more explicitly considered in the Operational Survival Plans. And, it is not at all made clear what the state or local decision-maker has to consider in order to make good and effective decisions for such strategic warning situations. Further, it is not at all apparent what strategic information inputs will be available to the state and local decision makers. The availability of such information inputs is crucial for the assisting of the state and local decision makers in taking appropriate actions under strategic warning conditions.

An Air Raid Warning** has been defined to be a "civilian warning used to notify civil defense authorities that an attack upon the United States is probable, imminent, or in progress. It is based on intelligence information,

* Reference(1), pp 8-9,

** Reference(60)

the military and political situation, and command decisions within NORAD." Within such a definition, Air Raid Warning would encompass strategic warning situations, as well as tactical warning. Presumably, the initial statement following the declaration of an Air Raid Warning, describing the cause for the warning, would make clear whether strategic warning or tactical warning is being considered. The warning time, of course, could depend on the strategic conditions that motivated the declaration of the Air Raid Warning.

At present, however, there is no standing operating procedure that allows handing down processed and graduated strategic information through the NAWAS System from the Area Warning Centers. And there appears to be no explicit procedure for handing down such processed strategic information, or strategic warning, from the National Warning Center, except, possibly, the initial Air Raid Warning.

If specific and effective warning-decision procedures are to be developed by the states and local communities, it appears desirable that such warning information receivers be provided with an indication of the nature and character of the strategic warning situation. This is most certainly the case when the set of possible actions that may be selected contains more than one elemental action, which of course is a trivial case.

Notably, the major population and industrial centers of the country would profit greatly by the provision of strategic warning. The added warning time would provide a very significant increase in the survivability of these populations. Whereas, the warning time obtained from tactical warning only might be around 15 minutes, with the improved strategic warning capability, the warning times might be in the order of hours, or even days.

Further, the decision rules for the selection of appropriate actions that correspond to given strategic warning situations, are not explicit in the present Operational Survival Plans. Thus, for example, it may merely be stated that an evacuation order may be issued if a given strategic warning situation holds. This example assumes that the state or local decision maker is able to "know" what course of action to take when, all of a sudden, he is confronted with a different strategic warning situation.

2.6 Current Warning Decisions

In the context of current civil defense warning , decisions can be classified into two decision groups:

Initial Decision

- 1) Sound the ALERT; or
- 2) Sound the TAKE-COVER; or
- 3) WAIT.

If the ALERT is to be sounded

Select the appropriate action (that should supplement such an alarm from a set of preplanned actions).

The Attack Warning Information provided by the Federal Government is intended to:

- Trigger the decision-making process
- Enable the choice of the most desirable alternative

2.7 The Limitations of Outdoor Warning Devices and NEAR

The inefficacy of outdoor-warning devices is discussed and the development of NEAR as a possible indoor warning device is noted. Although it is clear that any system of more effective warning devices is desirable, per se, it is pointed out that to avoid suboptimization the determination of optimal warning decision procedures should precede the design of hardware. On the other hand, present need dictates that innovations be introduced that do not interfere with our long-range objective for a better Civil Defense. The decision on NEAR, assuming its technical feasibility, is thus placed in the balance between present and future defenses.

To the present time, the only type of official alarm devices have been of the outdoor type. Frank B. Ellis, Director of the Office of Civil Defense, testified on August 2, 1961, before the Subcommittee on Military Operations of the Committee on Government Operations that the existing outdoor warning system

at present reaches only about 35% of the American people. This low percentage is due to the fact that a large proportion of the time, especially that of city dwellers, is spent indoors, where the warning device coverage is not significant. In fact, a study* made of the Washington, D. C. area showed that people spend 95% of their time indoors (of which 5% accounts for people inside closed automobiles).

In an attempt to obtain a significant improvement in the number of people warned, the Office of Civil Defense has sponsored the development of the National Emergency Alarm Repeater (NEAR). The NEAR System utilizes a compact audible warning device (receiver) that can be plugged into an ordinary 60-cycle wall socket. It is the result of a search for a system that would be highly reliable, available to everyone, and economical. The device would be activated by a low frequency** signal transmitted by a NEAR signal generator located at an electrical power generating station. The activating signal must last at least 10 seconds before it activates the alarm. This tends to reduce the possibility of false alarms (that might be produced by, for example, line surges). The alerting signal could then last for 50 seconds. Thus, an alarm could be received within one minute. Strong consideration is being given by the Federal Government to the integration of the NEAR System into the Attack Warning System.

The use of such an indoor warning device would further counter the unconcern that the public has developed regarding air raid sirens, as a result of the considerable amount of testing that has taken place in the last several years. The perception of an air raid siren depends on whether the subject is alerted or unalerted. Much of the siren response by unalerted observers stems from the interactions of individuals with one another. The spread of the reaction may take a few minutes - which may be too late in a ballistic missile attack. The reaction to warning must be immediate.

At any rate, it is quite clear that any system of more effective warning devices is strongly desirable. Thus, effective warning decision procedures are desirable which may more effectively employ the improved warning devices. To avoid suboptimization, it is better to predetermine optimal

* Reference (23)

** Between 210 and 270 cycles per second.

warning decision procedures, and then to design warning devices to meet the warning requirement, than to base procedures on existing or proposed equipment. The transcendence of the present threat, on the other hand, dictates that a balance between present and future defenses be maintained. Therefore, we admit present innovation that does not interfere with our long-range objective for a better civil defense.

2.8 Limitations of Existing Warning Decision Procedures

The limitations of warning decisions are pointed out in the context of existing Operational Survival Plans. 1) The procedures for warning decision are determined to be quite gross in nature, with decision-making aids absent; 2) the convening of public bodies, required by some states is found to delay decision; 3) the responsibilities assigned to the state and local decision-maker are shown to be impracticable; 4) nonuniformity of procedures for comparable localities is deemed to be a measure of their nonoptimality; 5) warning decision rules that are present have not been optimized to minimize losses; 6) extemporaneous judgement is apparently an inherent part of present warning decision; 7) the psychological shock of the receipt of attack warning might seriously degrade performance; 8) warning point operators at state and local level are not structured to initiate action, and 9) dependence on locating a Civil Defense Director before action can be initiated is yet another weak link in the warning decision chain.*

1. Grossness of Procedures

The warning decision procedures extant in the states and local communities are, as a whole, quite gross in nature. It is a very rare state plan that exhibits explicit warning decision-making aids and instructions for possible warning situations. In fact, many of the states merely sketch lightly and roughly the warning decision functions that must be performed. Thus, for example, the Operational Survival Plans of various political subdivisions may include such statements as - "the Director of Civil Defense will determine when a given area should evacuate, or disperse", without noting what specific warning circumstances would motivate such a general action, and also without noting what specific instructions should be given to the public or to the civil defense personnel.

* See footnote on page 47.

2. Convening of public bodies delays decisions

As an example of an undesirable feature of some operational procedures, some states and local communities require the convening of public bodies or public officials to reach agreement on the proper course of action to take, upon the receipt of an attack warning.

3. Impracticable responsibilities of state and local decision makers

Many of the state and local Operational Survival Plans imply that the responsibility for warning decision making rests on the State Director of Civil Defense, the local Director, or both. The state and local Directors of Civil Defense have to make a personal judgment with regard to the most appropriate instructions or orders to prescribe for any given warning situation. The implication is that the Directors of Civil Defense "know" what to do when a given warning situation arises. This tacitly assumes that the Civil Defense Directors determine the local threat from the NAWAS information, consider every possible factor that can affect the consequences of a prescribed action, carefully analyze the warning information against these factors, and after a careful balance of the consequences of each possible action, then prescribe that course of action which is most conducive to the primary mission of civil defense - the preservation of life and property.

The foregoing implies that the training, experience, and background of the Civil Defense Director permits him to make a rational optimal decision with regard to the best course of action to take. The implication is also that the evaluation, implicitly performed by the Directors of Civil Defense is rapid enough such that the prescription of any course of action is still effective, when executed. Clearly, there is no sense in giving instructions as to an appropriate course of action when it is too late to do anything about the threat.

Furthermore, it is implied, and sometimes stated, that the Directors of Civil Defense make the best use of the knowledge and advice of their staff officers, such as the Attack Warning Officers. Thus, presumably, for a given warning situation, the Civil Defense Director might call for a conference with his staff, to determine the appropriate course of action to take. The time consumed

in reaching a decision under such circumstances could be appreciable and could significantly reduce the warning effectiveness.

4. Nonuniformity a measure of nonoptimality

Since there is no uniform outline for optimum warning decision-making prescribed (recommended, or even suggested) to these various command echelons, the aggregate utility throughout the nation of the warning decision procedures is clearly far from optimal. This certainly follows since it is clear that the diversity in background and experience of the Civil Defense Directors and their staffs serves to produce a diversity of warning decision rules and criteria.

5. Warning decision rules are not optimized to minimize losses

There is considerable variability in the warning decision procedures from state to state and from local community to local community. The decision rules and criteria as well as the sets of actions considered are at variance throughout the various states and local communities. Further, there is no evidence that any extensive or intensive attempts at optimizing the warning decision rules have been performed at these various political subdivisions. Presumably, each individual Director of Civil Defense depends on his own personal judgment to determine what constitutes a good decision - what constitutes the best course of action to take. Thus, the aggregate utility of such individualistic warning decision procedures from a national standpoint once again, appears to be far from optimal.

6. Extemporaneous judgment inherent in present warning decision

The foregoing discussion has assumed that the various Civil Defense Directors are responsible for geographical areas which are similar as to their warning problem; that is, such areas of approximately equal populations are economically, industrially, etc., etc., similar. However, quite clearly as the character and nature of the warning region varies, the decision rules and criteria of the Civil Defense Directors should accommodate themselves to such a variation. Furthermore, the decision rules and criteria should also be sensitive to the season of the year, time of the day, weather conditions, etc. Such a variation in the

environment of the various warning areas has led some observers to conjecture that it is impossible to provide formal explicit warning decision rules or procedures. These same observers contend that the warning decision making would have to depend on the personal judgment of the Civil Defense Directors. This, of course, is tantamount to saying that we must be prepared to tolerate the consequences, however serious they may be, of possibly suboptimal decision-making.

7. Psychological shock may be a further bar to decision-maker

Further, the psychological shock of the receipt of an attack warning could degrade the performance of Civil Defense Directors or their designees in using judgment to select an action appropriate to the warning situation. The magnitude of the consequences which are possible in this thermonuclear age would exert severe stress on the decision-making capabilities of the person responsible for selecting the proper actions to take.

8. Warning point operators are not structured to initiate action

Most of the Warning Points in the country are located at Police or Sheriff's Headquarters in order to ensure a 24-hour operational capability. Police officers or sheriff's deputies, on communications duty, also serve as Warning Point operators in the NAWAS System. Clearly, such non-Civil Defense Personnel as these are not able to act immediately upon the receipt of an attack warning. Even though they probably act swiftly in disseminating the attack warning, they are not able to prescribe the appropriate actions that the public should take. Such a police officer, or deputy sheriff, has to get in touch with the Director of Civil Defense, or one of his staff, who is in a better position to prescribe the proper course of action. The time involved in reaching the appropriate responsible party may be appreciable, and, consequently reduces the warning time available to take Civil Defense action.

9. Dependence on locating Civil Defense Director a weak link

It is noted that in many localities the Director of Civil Defense, or the executive head of the political subdivision, are the only ones who can

make the momentous decision: whether to sound the ALERT (or the TAKE COVER) signal. Similarly, they are the only ones who are empowered to specify what specific course of action should be taken upon the sounding of the ALERT or what specific civil defense plan to implement into action. Searching for the Director to determine what civil defense action to take could prove in some instances to be a disaster to the local community involved.

An alternative is to allow the operator on duty at the Warning Point (or Secondary Warning Point) to select the appropriate course of action, from a set of possible actions, and then implement it. But, of course, if a relatively untrained Warning Post operator in Civil Defense is to perform such an action selection, then the procedure for selection must be well delineated and fairly simple. The Warning Point operator should have little difficulty in determining what course of action corresponds to each warning situation.

* (From page 43)

It might be worth conjecturing on the effectiveness of an anti-ICBM system which depends on a conference-type decision process for determining when and at what to shoot, after an ICBM has been sighted. A major difference between the OCD and the AICBM cases is that in the latter situation, the system is primarily composed of highly sophisticated electronic equipments which have to be designed. Consequently, the decision problems must be resolved beforehand. In general, since the OCD problems possess a major social element, we are inclined to believe that the problems will be resolved eventually.

3.0 RECOMMENDED RESEARCH

The background for the research program recommended below is to be found in Sec. 1.1.1 and 1.3 of this report wherein it is pointed out that action on warning is presently hampered by a localization-decision at state and local level. The recommendation for improvement, in Sec. 1.4, was that the localization-decision be made at Federal level and a Threat State be the main communication of warning information from Federal to local level.

To implement the above recommendation it is required that Threat States be defined and their number determined vis-a-vis the set of state and local actions available to meet the threats.

In broad outline a research program to determine the definition and number of Threat States might assume the following form.

Optimization of Threat States

Objective: Present warning decision is delayed by the necessity, at state and local level, to localize the threat by means of evaluating and interpreting NAWAS data, in its present form. Decisions would be more expeditiously influenced and actions contributing to survivability more readily activated by changing NAWAS input information from its present form to the improved form of categories of threat, or Threat States. It is the objective of the program to define the Threat States so as to minimize the expected loss and further, to determine the optimum number of categories of threat required for this purpose. Further outputs of the study would be the determination of the required operations at Federal level to effectuate the program and the detailing of further areas of research, if any, relating to its implementation.

Program: 1) A survey should be conducted of existing structured Threat State procedures, to serve as a background for the study. These procedures include those employed by the military services relating to military and non-military personnel at military installations, by Germany and England during World War II, and those in existence today in Europe.

2) Corresponding to each Threat State the set of optimal actions should be determined.

3) A study should be undertaken to properly accommodate changes in Threat State optima between small, middle-sized and large populations.

4) A measure of loss should be developed and related to each optimal action vis-a-vis Threat State.

5) A reasonable Threat State probability scale should be developed and introduced.

6) Parametric changes of definition and number of Threat States should be incorporated within the framework of solution provided in the Theoretical Background (below), and quantitative and qualitative conclusions drawn.

Theoretical Background: We may think of the continuum of threat as ranging from a situation in which no warning is contemplated, through a Strategic Warning situation, through a Tactical Warning situation and on through a point where a strike is imminent, as shown in Figure VIII.

No Warning Situation	Strategic Warning Situation	Tactical Warning Situation	Imminent Strike Situation
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THE THREAT CONTINUUM

Figure VIII

The problem, then, is how shall this continuous spectrum of threat be partitioned into threat categories T_1, T_2, \dots, T_m to serve to activate an optimal set of decisions and actions at state and local levels which minimize the resulting losses.

In particular: How many categories of threat should there be?

How should the Threat States be defined to best enable their implementation by action to meet the threat?

Corresponding to each Threat State, it is possible to employ any action of the set of actions available to the target area; namely, a_1, a_2, a_3, \dots , or a_n .

Associated with the employment of each action to a Threat State there is a loss, l_{ij} , where i is the Threat State and j is the action. Hence the set of losses due to employment of each action against Threat State is $l_{11}, l_{12}, l_{13}, \dots, l_{1n}$.

It is possible to form the Threat State and action matrix

$$\begin{pmatrix} l_{11} & l_{12} & \dots & l_{1n} \\ l_{21} & l_{22} & \dots & l_{2n} \\ l_{m1} & l_{m2} & \dots & l_{mn} \end{pmatrix}$$

where entry l_{ij} is the loss due to Threat State i and action a_j .

In general there is a probability p_i that the threat will be i , and

$$\sum_{i=1}^m p_i = 1$$

It can be assumed that the minimum loss corresponding to threat 1 is l_1 , or $l_1 = \min(l_{11}, l_{12}, \dots, l_{1n})$; the minimum loss corresponding to threat 2 is $l_2 = \min(l_{21}, l_{22}, \dots, l_{2n})$, ..., and the minimum loss corresponding to threat m is $l_m = \min(l_{m1}, l_{m2}, \dots, l_{mn})$.

Hence the expected loss, due to the given selection of m Threat States, is

$$L_m = p_1 l_1 + p_2 l_2 + \dots + p_m l_m$$

A further consideration of the problem makes it clear that L_m is not only a function of the number of Threat States but also of the definition of each. Consider m Threat States under different definitions. Let d_i represent the i^{th} definition of the Threat States, where $i = 1, 2, \dots, k$. Corresponding to each definition there is an associated probability of occurrence of the state of threat. Moreover there corresponds an action of the set a_1, a_2, \dots , or a_n .

which minimizes the loss under the Threat State. Let definition d_1 corresponding to the probability set $P_1^{(1)}, P_2^{(1)}, \dots, P_m^{(1)}$ respectively associated with Threat States $T_1^{(1)}, T_2^{(1)}, \dots, T_m^{(1)}$ be productive of the minimal individual losses $\ell_1^{(1)}, \ell_2^{(1)}, \dots, \ell_m^{(1)}$. Then it is clear that there exists a threat definition loss matrix, under the k definitions, namely

$$\begin{pmatrix} \ell_1^{(1)} & \ell_1^{(2)} & \dots & \ell_1^{(k)} \\ \ell_2^{(1)} & \ell_2^{(2)} & \dots & \ell_2^{(k)} \\ \vdots & \vdots & \ddots & \vdots \\ \ell_m^{(1)} & \ell_m^{(2)} & \dots & \ell_m^{(k)} \end{pmatrix}$$

To optimize the Threat State definition we must determine the definition of Threat State that produces the minimum of the set of $L_m^{(i)}, i = 1, 2, \dots, k$ namely,

$$\begin{aligned} L_m^{(1)} &= P_1^{(1)} \ell_1^{(1)} + P_2^{(1)} \ell_2^{(1)} + \dots + P_m^{(1)} \ell_m^{(1)} \\ L_m^{(2)} &= P_1^{(2)} \ell_1^{(2)} + P_2^{(2)} \ell_2^{(2)} + \dots + P_m^{(2)} \ell_m^{(2)} \\ &\vdots \\ L_m^{(k)} &= P_1^{(k)} \ell_1^{(k)} + P_2^{(k)} \ell_2^{(k)} + \dots + P_m^{(k)} \ell_m^{(k)}; \end{aligned}$$

Stated in another manner, it is necessary to determine:

$$L_m^{(min)} = \min_{0 < i \leq k} \{ L_m^{(i)} \} = \min_{0 < i \leq k} \left\{ \sum_{j=1}^m P_j^{(i)} \ell_j^{(i)} \right\}$$

Having determined the optimum definitions of Threat State one must now determine the optimum number. Assume that the number of possible Threat States ranges from $m = 1$ to $m = M$. It is obvious that the desired result is obtained by finding the minimum of the definition-minimized set, or

$$\min_{0 < m \leq M} \{ L_m^{(min)} \}.$$

This provides the theoretical optimum solution to the problem.

REFERENCES

1. National Plan for Civil Defense and Defense Mobilization, January 1959
2. Blum, R.H. and Klass, B., A Study of Public Response to Disaster Warnings, SRI Project No. IU-1640, Stanford Research Inst., June 1956
3. Brodie, B., Strategy in the Missile Age, Princeton University Press, Princeton, New Jersey, 1959
4. Carleton, D. E., Civil Defense at Local Government Level, Industrial College of the Armed Forces, Washington, D. C., (Pub. No. L60-15x) 18 March 1960, (Div. 18) AD-249-066, 16 January 1961
5. Dollins, C. B., A Preliminary Analysis of the Warning System, OCDM-SA-60-4 RM, Systems Analysis Division, Operations Research Office, OCDM, June 1, 1960
6. Dollins, C. G., Prospects for Space Age Warning, OCDM-SA-61-11 RM, Systems Analysis Division, Operations Research Office, OCDM, June 15, 1961
7. Garrett, Ralph L., A Brief Statement of Past and Present Social Sciences Research Conducted by the Former Office of Civil and Defense Mobilization and the Office of Civil Defense, Department of Defense, OCD, DOD, 1962
8. Goure, Leon, Civil Defense in the Soviet Union, University of California Press, 1962
9. Huebner, C.R., The Civil Defense Program of State of New York, 4 March 1960 (Pub. No. L60-141), Industrial College of the Armed Forces, Washington, D. C. AD-249 065 Div. 18, 16 January 1961
10. Intlekofer, J., Planning for Survival, Cornell Aeronautical Laboratory, October 23, 1961
11. Inderwiesen, F.H., Receivers for the National Emergency Alarm Repeater System, Electrical Engineering, September 1961
12. Kahn, H., Fromm E., and MacCoby, M., A Debate on the Question of Civil Defense, Commentary, January 1962, 23 pp.

13. Kahn, H., On Thermonuclear War, Princeton University Press, Princeton, New Jersey, 1961
14. Mack, R. W. and Baker, G. W., Disaster Study No. 15, The Occasion Instant, Disaster Research Group, National Academy of Sciences - National Research Council.
15. Mann, M., Could A Radar False Alarm Trigger Atomic War, Popular Science, April 1961
16. McDonald, James E., An Analysis of Civil Defense Hazards Being Created by Emplacement of Intercontinental Ballistic Missiles near Tucson, Arizona Academy of Science, Journal of the, v. 2, No. 1, pp. 3-19 (August 1961)
17. McFigure, A. C., Fallout Procedure, Radiological Division, Consolidated Erie County Office of Civil Defense, February 1960
18. Miller, Carl, Methods of Integration and Utilization of the Civil Defense Program, OCD, DOD, 1962
19. Morgenstern, O., The Question of National Defense, Vintage Books, New York, 1961
20. Supron, L. F. and Zverov, F. P., Medical and Civil Defense in Total War, State Publishing House of the Belorussian SSR (Translated by the Israel Program for Scientific Translation, Jerusalem 1961)
21. Scott, W. A., Public Reaction to a Surprise Civil Defense Alert in Oakland, California, Survey Research Center, Univ. of Michigan for FCDA.
22. Witze, C., Can an Airborne Alert Prevent a Space-Age Pearl Harbor, Air Force Magazine, March 1960
23. Wang, et al, Air Raid Warning in the Missile Era, ORO, The Johns Hopkins University, July 1960
24. Albany County, Civil Defense Plans, Albany County, New York
25. Allegany County, Civil Defense Plans, Allegany County, New York
26. Buffalo, N. Y., Civil Defense Program, Bell Aircraft Corporation, Wheatfield Plant, July 7, 1951
27. Buffalo Target-Support Area, Communications Plan and Annex, December 15, 1960
28. Cattaraugus County, Operational Survival Plan, Cattaraugus County, New York

29. Chautauqua County, City of Dunkirk, Operational Plans for Civil Defense, Revised December 5, 1961, Chautauqua County, N.Y.
30. (State of) Delaware Operational Survival Plan , December 1, 1958
31. (State of) Delaware Operational Survival Plan, Compilation of Facilities and Resources with Standard Locations, Delaware Department of Civil Defense (no date)
32. (State of) Delaware OSP, Kent County
33. (State of) Delaware OSP, New Castle County (undated)
34. (State of) Delaware OSP, Sussex County
35. (State of) Delaware OSP, City of Wilmington
36. Concept of Civil Defense in Delaware, Delaware Department of Civil Defense, February 20, 1962
37. Erie County, Basic Plan, OCD, Erie County, New York
38. Erie County, Attack Warning Service Manual, Dissemiation Plan, Erie County, N.Y., August 1961
39. Erie County Communications Plan, OCD Erie County, New York April 1962
40. Manual for Civil Defense Organization in Towns, OCD, Erie County, New York, Revised May 15, 1961
41. Organization of Sectors, City of Buffalo, OCD, Erie County, New York, Revised March 1, 1960
42. Aid Check Point Manual, OCD, Erie County, New York, January 1957
43. Erie County's Civil Defense STATUS QUO revised July 1, 1960
44. Zone Manual for Operations and Training, OCD, Erie County, July 15, 1961
45. Location of Civil Defense Air Raid Sirens by Numbers (Erie County, undated)
46. Cross Index of Civil Defense Air Raid Sirens, Erie County, February 1961
47. Monroe County, Attack Warning and Information S.O.P., Monroe, New York, 15 August 1962

48. State of New Hampshire Civil Defense Plan, 30 June 1958
49. New York City, Civil Defense Plans, New York, N.Y.
50. New York State OSP, Volume 1, Basic Plan, 1958
New York State OSP, Volume 2, Service Annexes, Part 1, (undated)
51. Pennsylvania Civil Defense Survival Plan, Erie County, Pennsylvania
52. Pennsylvania Operational Survival Plan, Reading, Pennsylvania
53. Operational Survival Plan for the State of Virginia
54. Wyoming County, Civil Defense Plans, Wyoming County, N.Y.
55. Annual Report 1959 OCDM
56. Atomic Warfare Defense, Navy Training Courses, U.S.G.P.O., 1955
57. Basic Civil Defense, June 1959, OCDM
58. Civil Defense - 1961 Hearings before a Subcommittee of the Committee on Government Operations, House of Representatives, Eighty-Seventh Congress, August 1, 2, 3, 4, 7, 8, and 9, 1961 USGPO 1961
59. Directory of Warning Points, Department of Defense, Office of Civil Defense, Warning Office, Battle Creek, Michigan
60. Federal Warnings Operations Manual, November 1960
61. Grandma's Pantry . . ., New York State Civil Defense Commission
124 E. 28 Street, New York 16, New York
62. Highway Needs for Civil Defense, U.S. Department of Commerce
October 1956
63. House of Representatives, U.S. Government Hearings before a Subcommittee of the Committee on Government Operations, 87th Congress, First Session. Civil Defense, 1961, Washington, D.C., 1961
64. New Civil Defense Program - Ninth Report by the Committee on Government Operations USGPO 1961
65. Report on a Study of Non-Military Defense, Rand Report R-322-RC, July 1, 1958
66. A Preliminary Analysis of Nonmilitary Defense, OR-5902, Operations Research Office, OCDM, January 1959
67. National Research Convention, 8-10 February 1960 Proceedings of the Meeting on Environmental Engineering in Protective Shelters

68. (State of) New York Civil Defense Commission, YOU and Civil Defense
69. New York State Defense Emergency Act 1951-1961 New York State Civil Defense Commission
70. Psychological and Social Adjustment in a Simulated Shelter, American Institute for Research, July 1961
71. RACES, OCDM, October 1960
72. Radioactive Fallout on the Farm, U.S. Department of Agriculture, 1961
73. Regional Plans for Civil Defense and Defense Mobilization, OCDM Region 2, Olney, Maryland.
74. Rural Family Defense, Federal Civil Defense Administration, Battle Creek, June 1957, Revised
75. Ten for Survival: Survive Nuclear Attack, Reprinted July 1961, OCDM
76. 10 Steps to Industrial Survival, OCDM, April 1960
77. New Developments: New Warning Systems, Ordnance, January, February 1961
78. The World Almanac 1961

TRIPS AND VISITORS

May 9, 10, 11, 1962	Contractors' Symposium, Arlington, Virginia
June 12, 1962	Conference, Buffalo, New York Col. Snyder, Deputy County Director and Mr. McEvoy, Communications Officer of Erie County
June 25, 1962	Cornell Aeronautical Laboratory Mr. McEvoy
July 20, 1962	New York State Control Center Mr. McGrath, Attack Warning Officer
July 26, 1962	Contractors' Conference, Pentagon Messrs. Brown and Kerr, OCD
August 10, 1962	Pentagon Messrs. Brown and Kerr
August 24, 1962	Region 2 OCD Headquarters Messrs. Scarborough, Regional Director; Huber, Director of State Field Operation; Oscanyon, Attack Warning Officer, Technical Operations; White
August 27, 28, 29 1962	Pentagon, OCD Library Messrs. Brown; Roderick, Director of Warning Branch, Technical Operations; Owen, State and Local Division, OCD
September 11, 1962	26th OCD Warning Center, Syracuse, N. Y. Messrs. Collinson, Director; and Carney
September 27, 1962	Region 1, OCD Headquarters Messrs. Wiegand, State Field Operations Officer; and McLeod, Director of Technical Operations
October 3, 1962	Cornell Aeronautical Laboratory Messrs. Brown and Kerr

[illegible][illegible]

APPENDIX I ATTACK WARNING ENVIRONMENT

I. Introduction

The provision of a satisfactory attack warning system requires that there be available: tactical and strategic information gathering and processing media, an attack warning dissemination network, and appropriate action selection structure and procedures.

The Warning Decision Study requires, in effect, the concentration of attention on the latter item. However, all of the above items are highly inter-dependent. Consequently, an examination of a representation of the attack warning dissemination network (the Attack Warning System) is performed. The representation is in the sense that a set of three states is selected as a representative cross-section of the set of fifty states. The data is confirmed against a set of six additional states.

Those items concerning the National Warning System which are considered to be pertinent to the study are presented. The same criterion is used in the discussion of the State Warning Procedures for the States of New York, Delaware, and New Hampshire. Whenever possible, the local procedures in the states are also considered. In the study of the foregoing, specific attention is directed at those factors that affect the attack warning decision making functions.

A. Targets

The potential enemy could attack a large number of targets within the United States. It is unlikely that every possible target would be attacked either in an initial nuclear assault or in subsequent attacks. Neither the total number of intended targets nor the pattern of attack can be predicted.

Military bases of our nuclear retaliatory forces, other important military installations, and centers of government, industry and population would be principal targets of nuclear attack.

These target categories* include:

* Identification of specific targets within these categories is the responsibility of the respective state Civil Defense authorities. The Federal Government, through the OCD Regional offices, assists the states in identifying probable target areas.

- 1) Operational bases of the Strategic Air Command and installations of the Continental Air Defense Command, including civil and military airfields with major servicing and maintenance facilities and hard-surface runways at least 7000 feet in length in mean sea level equivalent.
- 2) Major military command and control headquarters such as the Pentagon and headquarters of the North American Air Defense Command, Strategic Air Command, Continental Air Defense Command, and Naval Sea Frontiers.
- 3) Major harbors, naval bases and military supply depots.
- 4) Major military installations on which major Army and Fleet Marine forces are stationed.
- 5) Standard Metropolitan areas containing population concentrations of at least 150,000 inhabitants.
- 6) Areas with high concentration of industry, Atomic Energy Commission production facilities, major dams, and major power, transportation, communications, and petroleum - handling facilities.*

B. Definition of Warning

The National Plan for Civil Defense defines warning to be the alerting of people to the threat of extraordinary danger and the related effects of danger. This includes the collection, evaluation, and dissemination of warning information by Federal, State and Local governments and the facilities needed to achieve this.

A further description of warning that may be in closer correspondence with civil defense procedures is - - the signalling to attract attention with the subsequent or simultaneous description of the imminent danger and the provision of appropriate actions to be taken by the receiving party.

The National Plan also states (Annex 1) that there are two types of warning which the United States might have concerning an enemy attack: strategic warning - evidence of enemy intentions to launch an attack against the United States; and the tactical warning - knowledge of probable attack after it has been launched. This is provided by mechanical or electronic means. However,

* Reference (1)

it is noted that attack could come without warning. The detonation of the first weapon could serve as warning for the entire country.

II. THE ATTACK WARNING SYSTEM

The National Plan for Civil Defense specifies that the federal, state, and local levels of government are responsible for the establishment of an Attack Warning System for the purpose of disseminating attack warnings down through the various levels of government to the people. The necessary actions that should be taken upon the receipt of such a warning are to be prescribed by the appropriate governing body. Standing operating procedures in state and local plans and mutual-aid agreements predicate the actions to be taken. Such actions can involve: evacuation and dispersal of populations located within target cities and target areas, if time and conditions permit; and the seeking of the best shelter available, etc.

Where outdoor warning signals are used to warn the public of a probable or imminent attack, they consist of: the ALERT signal - which instructs the public to take action as directed by the local governments; and the TAKE COVER signal - which instructs the public to take cover immediately in the best shelter available.

A. The National Warning System

The National Warning System (NAWAS) is established to form the federal portion of the Attack Warning System and consists of full-period, private-line voice circuits leased from the telephone companies, with signalling devices provided where required. NAWAS, as shown in Figure I-1 declares and then disseminates the attack warnings down to the state and local governments for further dissemination of warnings, and for the initiation of respective actions. NAWAS is designed specifically for simultaneous issuance of warnings from a single source - the National Warning Center - to all warning points in the National Warning System.

Basically, the National Warning System consists of the Warning Circuit and the Control Circuit.

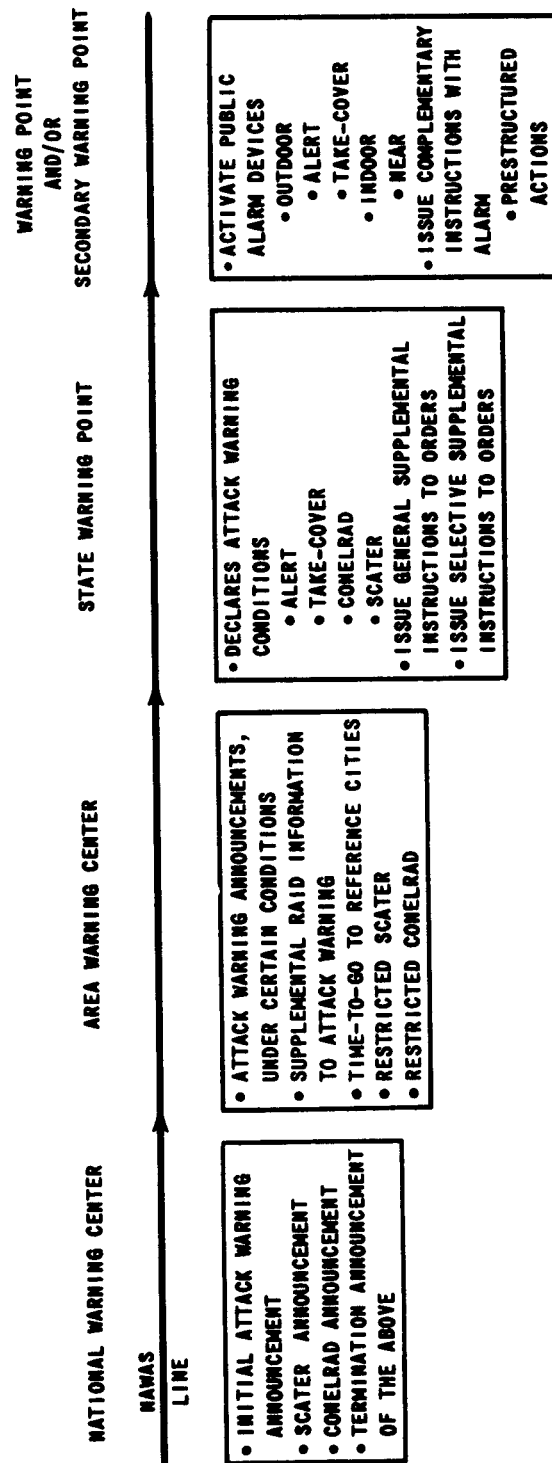


Figure I-1 NATIONAL WARNING SYSTEM

A1. The Warning Circuit

The nation is divided into six mutually exclusive Warning Areas, with a Warning Center located within each Warning Area. These Warning Centers are operated by the North American Air Defense Command (NORAD). There is an OCD Warning Officer stationed at each Warning Center. The function of the Warning Circuit is to provide a communications network which allows the Warning Centers to disseminate emergency information to all ancillary Warning Points connected to the Warning Circuit. The operations of the Area Warning Circuit are controlled by the respective Warning Centers.

Each state has one or more Warning Points. These Warning Points are located to provide a direct warning capability to principal cities. Any state having more than one Warning Point is provided a voice circuit connecting a State Warning Point with the other Warning Points in the state. This circuit is connected to the Area Warning Circuit at the State Warning Point and also forms a part of NAWAS. The State Warning Point maintains supervision of the circuit within its state. Warning Points receive warnings and other emergency information directly from the National or Area Warning Center and also receive subsequent instructions from the respective State Warning Point.

A2. The Control Circuit

The Control Circuit provides a communications medium for lateral telling of tactical operational information between Warning Centers and Operational Headquarters, and is used to control and coordinate the activities of all Warning Centers. Normally, the Warning Circuit is separated into Area Warning Circuits. After prior coordination between Warning Centers by means of the Control Circuit, the Warning Circuits are connected into one national circuit for any necessary announcements, tests, etc. The Control Circuit connects the OCD Warning Centers, OCD Regions, Operational Headquarters, Director's Office, and the Classified Location. A grouping key is installed at the OCD Warning Centers which, when operated, connects the Control Circuit with the Area Warning Circuits. The primary use of this key is to provide the capability for the issuance of operational information simultaneously to all NAWAS stations. A secondary use of this key is to provide a bridging capability wherever there is a circuit interruption in an Area Warning Circuit. It is possible for the OCD National Warning Center to notify all stations (or any number of stations) on the Control

Circuit simultaneously through selective dialing whenever the Defense Readiness Condition. requires such notification.

B. NAWAS Decision Points

Each of the following types of points in NAWAS exercises some form of control over the operations of a subcircuit of the Warning Circuit, except for the terminal Warning Point (i. e., the end recipient of the warning information). The decision-point types, within NAWAS are National Warning Center, Area Warning Center, State Warning Point, Warning Point, and Secondary Warning Point (for certain states). For some states, the Warning Point is the terminal point for NAWAS; for others, e. g., New York State, the NAWAS terminal point is the Secondary Warning Point. Each is also a branch point, in the sense that several warning lines emerge from a single incoming higher level line (higher in the NAWAS hierarchy). Each is also responsible for issuing respective instructions, orders, and/or information.

The information issued by the National Warning Center to NAWAS are Initial Attack Warning Announcement, SCATER announcements, CONELRAD announcements, and termination announcements of the above.

The information types issued by the Area Warning Centers to NAWAS upon on the onset of hostilities are: Supplemental raid information to attack warning, time-to-go reference cities, restricted SCATER announcements, restricted CONELRAD announcements, and attack warning announcements, under certain conditions.

C. State and Local Government Responsibilities

The National Plan states that the state and local governments are responsible not only for disseminating attack warnings and other emergency information throughout their political jurisdiction, but also for prescribing the actions to be taken by the respective government and the public upon the receipt of the warning. The National Plan also states that: procedures will be established and tested at all levels for the dissemination of all types of warning received through the Attack Warning System; and that criteria and procedures will be established for the sounding of the ALERT and TAKE COVER signals.

The following are the types of actions performed by State Warning Points: declare Attack Warning condition, namely ALERT condition, TAKE COVER condition, CONELRAD condition, and the SCATER condition. These issue General Supplemental Instructions or Orders and also issue selective supplemental instructions or orders.

The following are the types of actions performed by the terminal warning points upon receipt of attack warning: activate public alarm devices such as outdoor devices, e.g., sirens, horns, etc.,... for an ALERT signal, or a TAKE COVER signal; and indoor devices, such as NEAR.

Issue simultaneously with the above (or, subsequently) instructions or orders that supplement or complement the alarm. The set of instructions or orders that may be taken upon the receipt of the warning is prestructured.

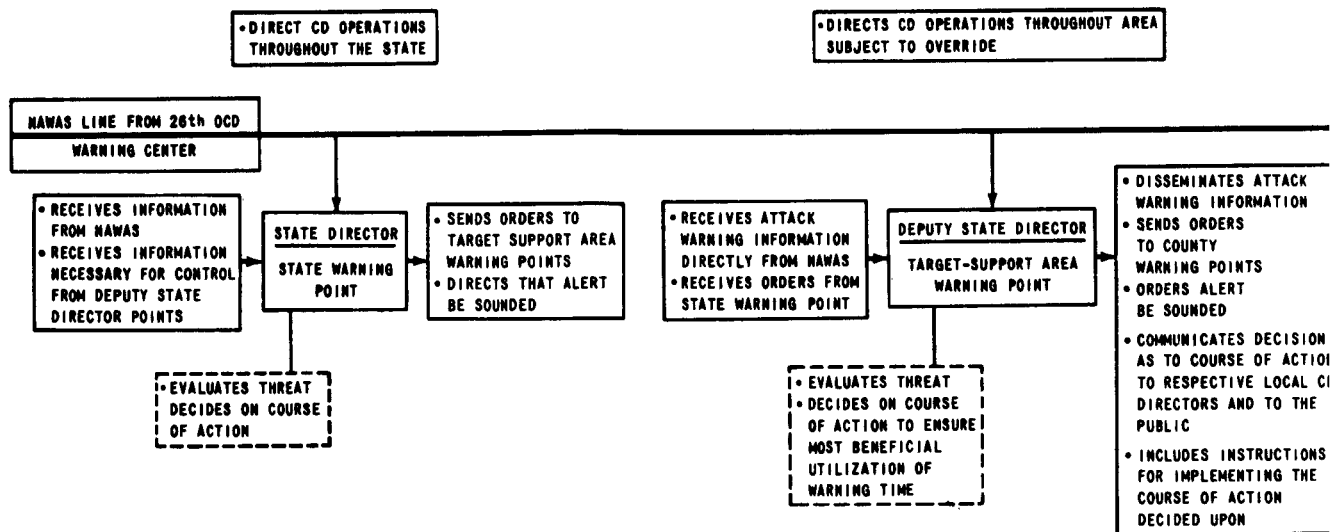
Notify key CD personnel by telephone or radio (depending on local operating procedures), general notification and selective notification.

III. SELECTED STATE ATTACK-WARNING STRUCTURES

A. The State of New York Attack-Warning Structure

The New York State link in the attack-warning chain is shown in Figure I-2. New York State is divided into twelve Target-Support Areas (New York State Operational Survival Plan - 1958). Each Target-Support Area has as its focal point, a city or county considered to be a most likely target for enemy attack because of its military importance, strategic location, or concentration of population or industry. Each target city (or county) is assigned a group of counties and/or cities, called the Support area, which together with the Target Area, constitute the Target-Support Area. The Target Area and/or the Support Area comes to the aid of the other in the event of an attack.

In the event of a Civil Defense emergency, the State Director of Civil Defense and his staff directs Civil Defense operations throughout the state. Among the responsibilities of the State Director is the command of the State CD Commission's staff at the State CD Control Center.



*DIRECTS MOBILIZATION, EMPLOYMENT AND COORDINATION OF ALL CD FORCES: COORDINATES CONELRAD BROADCASTING THROUGHOUT AREA.

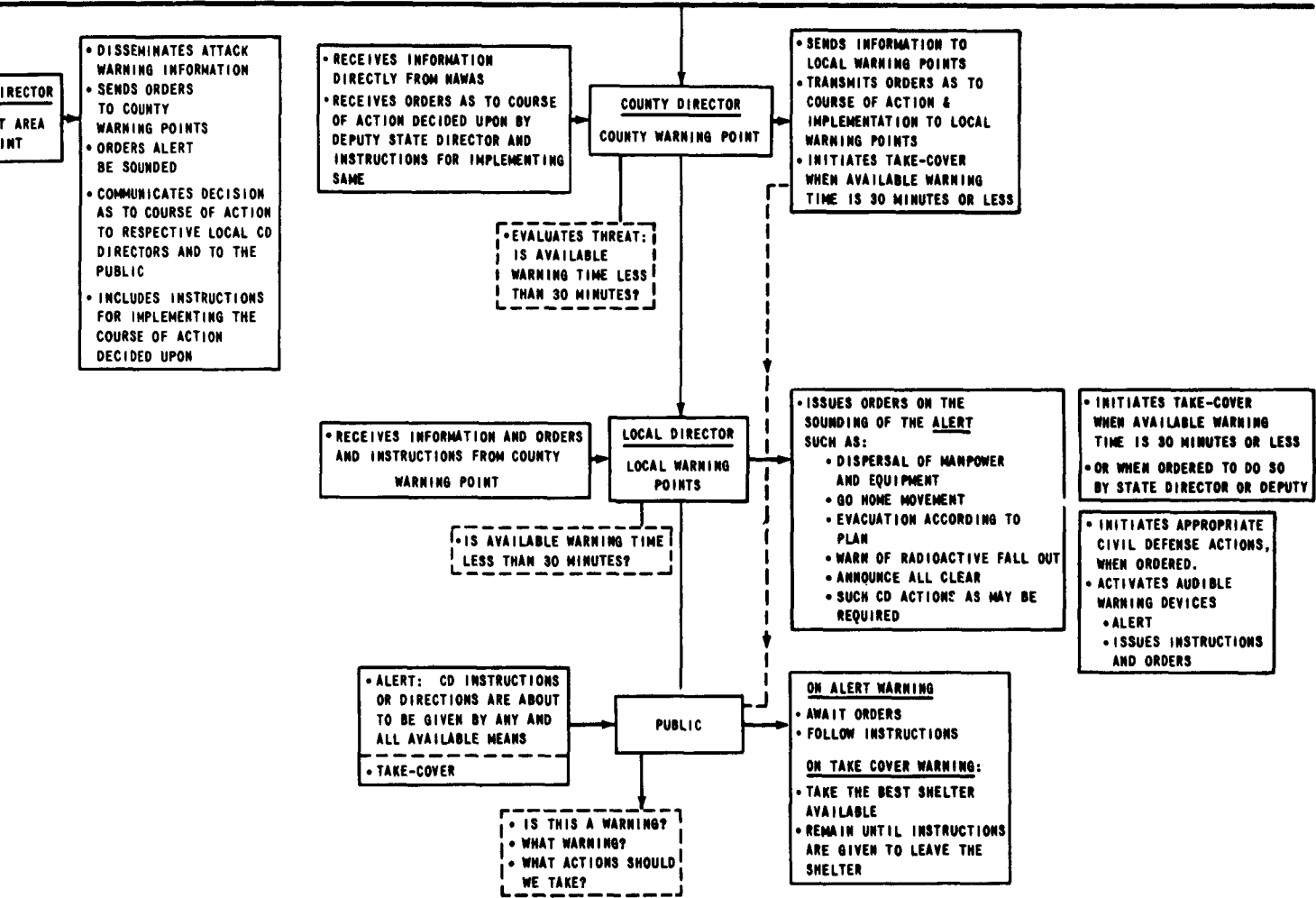
**SOME COUNTIES HAVE A SINGLE CONTROL OF ALL THE PUBLIC ACTION SIRENS.

Figure 1-2 NEW YORK STATE LINK IN
ATTACK WARNING CHAIN



THROUGHOUT AREA

• DIRECTS CD OPERATIONS THROUGHOUT COUNTY
SUBJECT TO OVERRIDE



Each of the Target-Support Areas is under the direction of a Deputy State Director who is appointed by the State Civil Defense Director. In time of emergency, the Deputy State Director directs Civil Defense operations throughout his Target-Support Area.

It is the responsibility of the Deputy State Directors, in the event of an emergency to: receive and disseminate warning information, decide upon a course of action to be followed in their Target-Support Area to ensure the most beneficial utilization of warning time, communicate this course of action to the local CD Directors within their Target-Support Area and to the public, including the instructions for implementing the course of action he has decided upon, coordinate CONELRAD broadcasting in Target-Support Area, direct mobilization and employment of CD forces in Target-Support Area, coordinate all CD forces in Target-Support Area.

There is at least one NAWAS Warning Point located within each Target-Support Area. The State Warning Point, which exercises control over the Warning Points in the state, is located at Albany, the state capitol. The State of New York has also instituted NAWAS extensions at its Secondary Warning Points. A Secondary Warning Point is located within each county of a Target-Support Area. The control of the operations of the Secondary Warning Points within a Target-Support Area is performed at one of the Warning Points within the given Target-Support Area (there are 12 Target-Support Areas and 14 Warning Points within the State of New York). Such control is made possible by the installation of equipment at the Warning Points, which is identical to that required at the State Warning Points. The function of the Secondary Warning Point is to transmit attack warning information to the Subsidiary Warning Points as well as to the responsible Civil Defense Director.

A Subsidiary Warning Point is an installation within a country which receives attack warning information from a Secondary Warning Point for the initiation of appropriate civil defense actions. Such actions are exemplified by the activation of the audible warning devices, such as sirens. In some instances, the Warning Points also function as Secondary Warning Points for the counties of their location, as well as Subsidiary Warning Points. However, Warning Points may discharge their function as Secondary and Subsidiary

Warning Points simultaneously with, but not before, they have disseminated the attack warnings and announcements to the counties of their responsibility.

There are two signals authorized to be sounded over the public warning devices in the State of New York - the ALERT signal and the TAKE COVER signal. The ALERT signal, when sounded, signifies that civil defense instructions or directions are about to be given to the public by any or all means available. Each local civil defense director, or his designee, when directed by the State Civil Defense Director, or by his deputies or designees, sounds the ALERT signal within his jurisdiction and follows it by the issuance of instructions and orders. The TAKE-COVER signal, when sounded, signifies that an attack is imminent and that all must immediately seek the best shelter available and remain there until civil defense instructions are issued to the public to leave the shelter. Each local civil defense director, or his designee, orders the TAKE-COVER signal to be sounded within his jurisdiction when the available warning time is 30 minutes or less, or when ordered to do so by the State Director, or his deputies or designees. Either of these two signals may be sounded to the exclusion of the other. There is no established sequence for the sounding of these signals.

Upon the sounding of the ALERT signal, it is followed by the issuance of instructions, such as: to order a dispersal of manpower and equipment, go home movement, evacuation according to plans (limited or general), to warn of radioactive fallout, to announce an ALL CLEAR, or to order such other CD action as may be required.

The dissemination of the attack warning from the County Warning Points to the Subsidiary Warning Points is performed by various means throughout the counties. Some counties utilize radio dissemination, others telephone fan-out networks, etc. Some counties have push-button control of all the public action sirens in the county, from the County Warning Point. Some counties use a radio signal to activate all the public action sirens in the county. Sirens are still considered the principal audible warning device, and are complemented by horns and whistles. It has been stated (by the New York State Attack Warning Officer) that approximately sixty percent of the

state is covered by sirens. Presumably, this geographic coverage covers the more densely populated portions of the state. No consideration has been given at the New York state level to the integration of the NEAR system into the State Attack Warning System. The State of New York does not believe that the utilization of selective warning is of any significant help. Consequently, no consideration has been given to its introduction into the state procedures.

Discussion of Warning Decisions

The Warning Centers disseminate the warning time to the Reference Cities in the Warning Area. Each local CD Area throughout the country is associated with one or more of the given Reference Cities. The Reference Cities, corresponding to Aiming Areas in New York State, are selected by considering potential air vehicle (aircraft or missiles) courses or trajectories. Thus, presumably, the criterion for assignment of Reference Cities is to select the closest one to a given Aiming Area along a potential trajectory path.

As noted earlier, the TAKE COVER signal is ordered by the local CD Director when the available warning time is 30 minutes or less. However, the State Director of CD, or his deputies, or designees, can also order the local director of CD to sound the TAKE-COVER signal. These higher command echelons exercise such authority whenever their experience and training dictates that they do so. They have no prestructured set of rules or procedures to aid them in making such a decision. They have no explicit criterion for decision or principle of choice available to them (personal communication by W. McGrath, New York State Control Center, Albany, New York).

It should be apparent that as the warning time decreases and approaches 30 minutes, the decision-making problem becomes increasingly difficult. A possible conflict between the states and local levels of command may result if the criterion for decision is only based on warning time. Presumably, then, the higher command's prerogative to sound the TAKE COVER may be based on other factors besides warning time. These factors would probably be encompassed within the experience and training of the decision maker, as well as the nature of the warning situation.

There is no set of rules or procedures available to the State CD Director, or his deputies, or designees, that helps him in determining when to order the local CD Directors to sound the ALERT signal. It has been stated that there is little likelihood that the ALERT signal will be sounded at the state level in New York State (by W. McGrath). Consequently, the most likely command echelon, responsible for directing the sounding of the ALERT signal, is the Deputy State Director level (the Director of the Aiming Area).

These command echelons presumably rely on their background to help them in determining whether the ALERT should be directed to be sounded. Under such conditions, clearly, the decision rule employed varies from individual to individual, i. e., from Director to Director.

The State of New York recognizes that the ALERT signal has little meaning by itself. The State procedures require the issuance of instructions or orders simultaneously or subsequent to the sounding of the ALERT. The possible actions which may be required upon the sounding of the ALERT are manifold. However, there are no explicit procedures or decision aids available to the various CD Directors that help them in determining the appropriate action to take for a given warning situation. Here, once again, the Directors must depend on their experience and training to help them make such decisions. It is further noted that these various director levels attempt to make optimal use of the knowledge and advice of their staff officers, such as the Attack Warning Officers.

Some consideration is being given, in the State of New York, to the elimination of the ALERT signal from the State warning procedures. The justification being offered in support of this is that the public tends to be confused in discriminating between the ALERT and the TAKE COVER signals. A further argument against the utilization of the ALERT signal is that it has little utility by itself; it must be accompanied by the necessary instructions or orders through some other information medium (say the emergency radio broadcast system).

The elimination of the ALERT certainly implies the reduction of the number of possible actions that may be required by the public. Thus, even

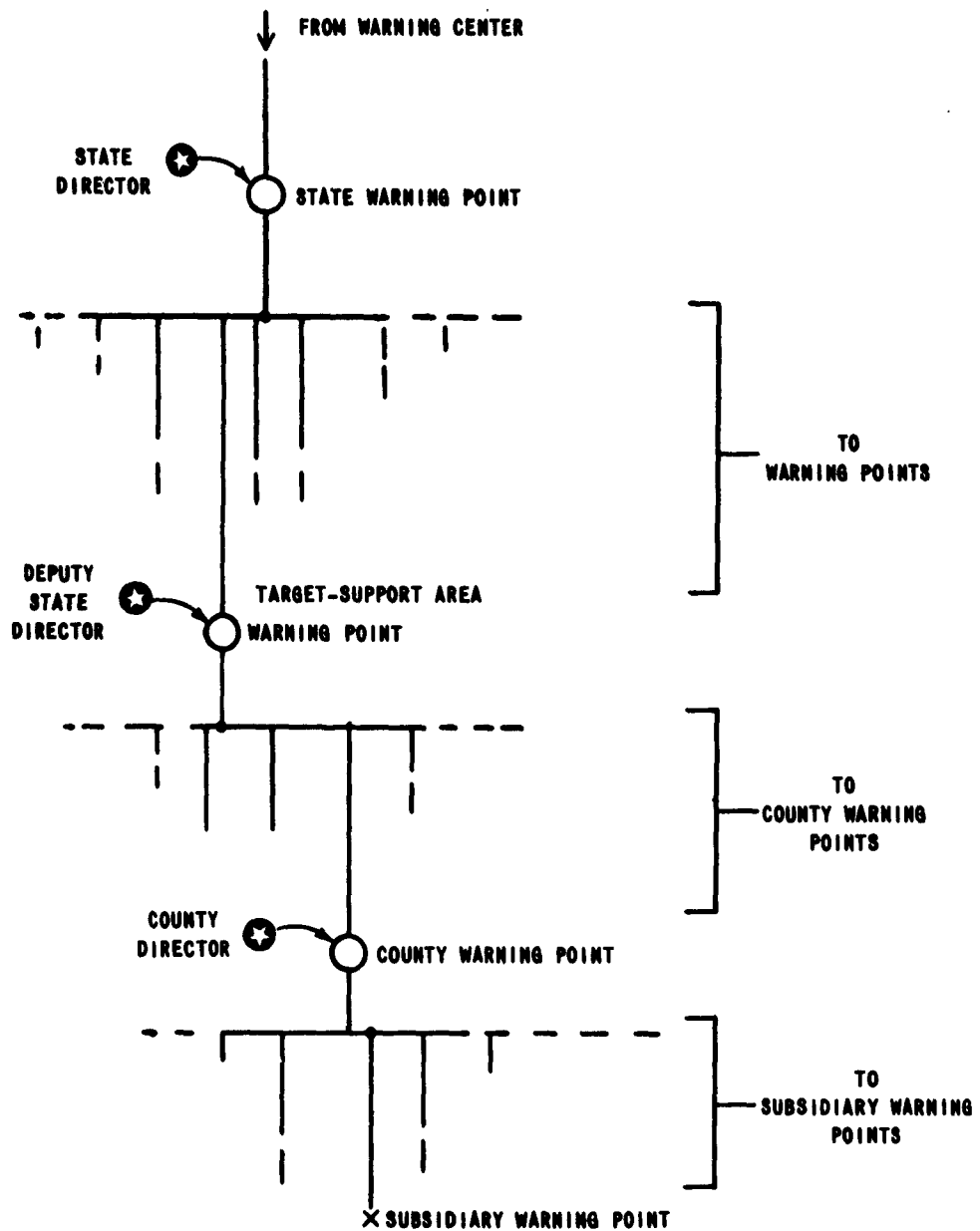


Figure 1-3 NEW YORK STATE ATTACK WARNING NETWORK

though the choice situation is apparently simplified, the flexibility which would otherwise be available is reduced. For example, the elimination of the ALERT eliminates one of the means for erasing a false alarm, as well as a means of resuming the unalerted state after the threat (e.g., an accidental ICBM strike) has passed.*

It appears reasonable to assume that some conditions may emerge which require selective alerting. For example, the sensing of a single ballistic track aimed at the Albany area may require the TAKE COVER signal to be sounded only over the Albany area (if the 30 minute criterion is satisfied). The remaining part of the country might be placed under either an ALERT or stand by for further information from NORAD Hdqs. What type of warning is given to the rest of the country might depend on the strategic situation at the time.

Figure I-3 illustrates the State Attack Warning Network and the decision making points.

B. The State of Delaware Attack-Warning Structure

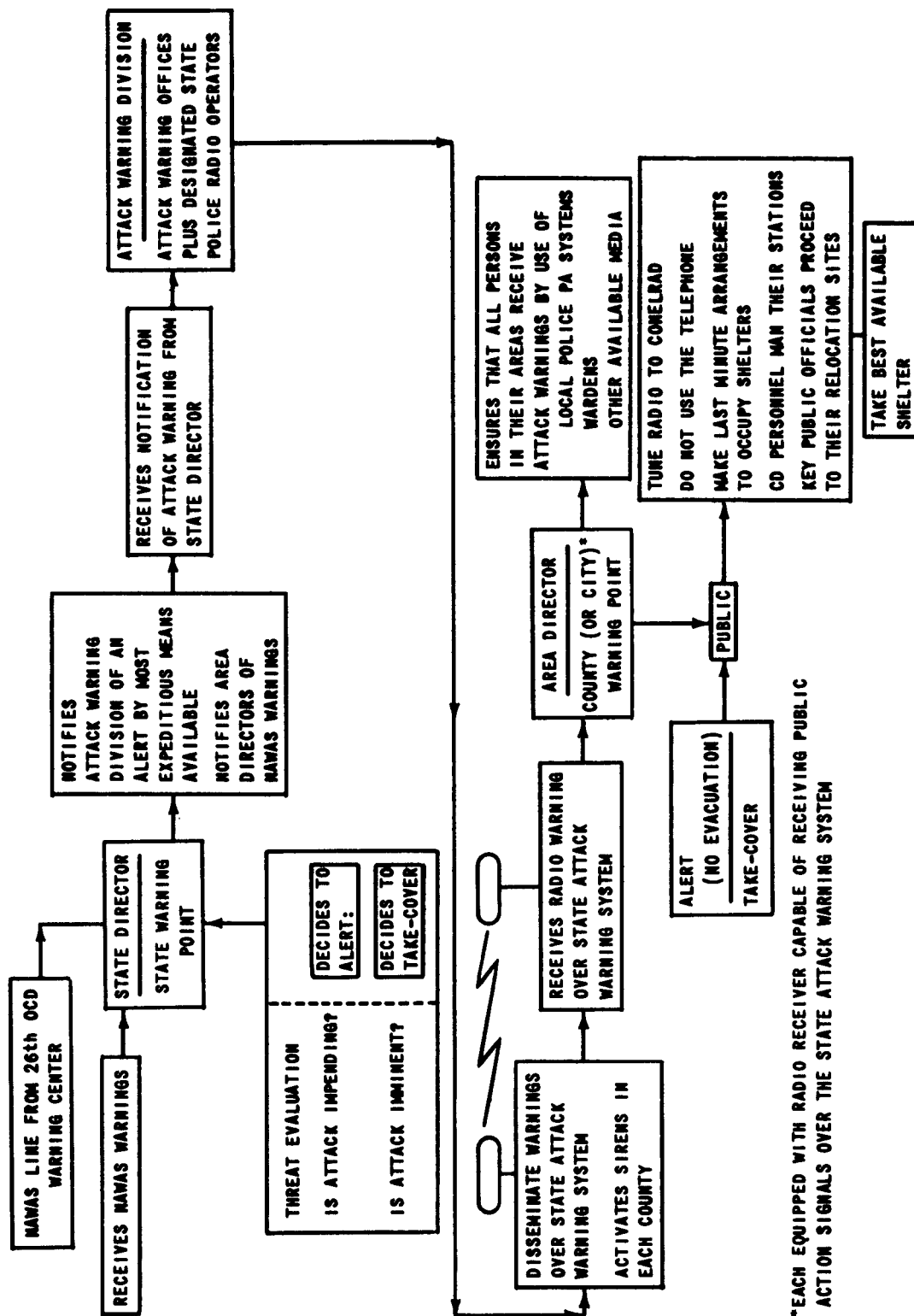
The State of Delaware link in the attack warning chain is depicted in Figure I-4. The state is divided into four areas for civil defense administrative and operational purposes (State of Delaware Operational Survival Plan - 1958).

City of Wilmington area
New Castle County area
Kent County area
Sussex County area.

Each of these areas is under an Area Director of Civil Defense. The State Director of Civil Defense is the executive head of civil defense activities in the state, subject to the direction and control of the Governor, and is responsible for administering state operations during emergency.

The State Director of Civil Defense is charged with the responsibility

* In light of the above example, it is evident that a first step is to relate Threat States to the set of available actions, as discussed in Section 3.0, Recommended Research, before making a final choice of signals and devices.



*EACH EQUIPPED WITH RADIO RECEIVER CAPABLE OF RECEIVING PUBLIC ACTION SIGNALS OVER THE STATE ATTACK WARNING SYSTEM

Figure 1-4 STATE OF DELAWARE LINK IN ATTACK WARNING CHAIN

of notifying the Attack Warning Division of an alert by the most expeditious means available. He is further charged with the parallel responsibility of notifying the Area Civil Defense Directors of warnings received over NAWAS, during normal duty hours when the State Control Center (located at Delaware City) is in operation. The State Attack Warning Division consists of an Attack Warning Officer and designated State Police radio operators.

The effectiveness of the State Attack Warning System is dependent upon radio tone signals to activate every warning device in Delaware. The State maintains and operates the only equipment capable of extending the radio tone signals upon the receipt of a warning of a probable enemy attack or other warnings from NAWAS.

Each county has at least one specially equipped radio receiver capable of receiving public action signals over the State Attack Warning System.

Police radio operators from Troops 1, 2, 3, 4, 5 disseminate warnings and intelligence received over the State Attack Warning System. Troops 2, 3 and 4 activate the public action signals. Troop 2 activates the sirens in New Castle County. Troop 3 activate the sirens in Kent County. Troop 4 activates the sirens in Sussex County.

There are two Key Warning Points,* located at Dover and Delaware City. The State Warning Point, located at Dover, is operated and maintained by Troop 3, Delaware State Police. An alternate State Warning Point is maintained at the State Control Center, Delaware City, but does not disseminate or acknowledge warnings unless the primary Warning Point at Dover is inoperable. The alternate State Warning Point is not equipped to disseminate radio tones for activation of the public action sirens.

New York City is the reference city for Delaware for attack warning purposes. Warning information pertaining to time and distance is based on this geographical reference point.

The County or City Attack-Warning Service is responsible for ensuring that all persons in their areas receive attack warnings by use of local police public address systems, wardens, and other available media of notification.

* Reference (30)

The State of Delaware has two accepted public action signals: the ALERT signal, and the TAKE COVER signal.

The decision rules for the sounding of the public action sirens in the State of Delaware have been revised, as of 20 February 1962. The possibility that an attack may be launched utilizing ICBM's and submarine launched missiles, carrying nuclear weapons, has strongly influenced the character of the standing operating procedures. Notably, evacuation is no longer considered an acceptable action to take upon the sounding of the ALERT signal.

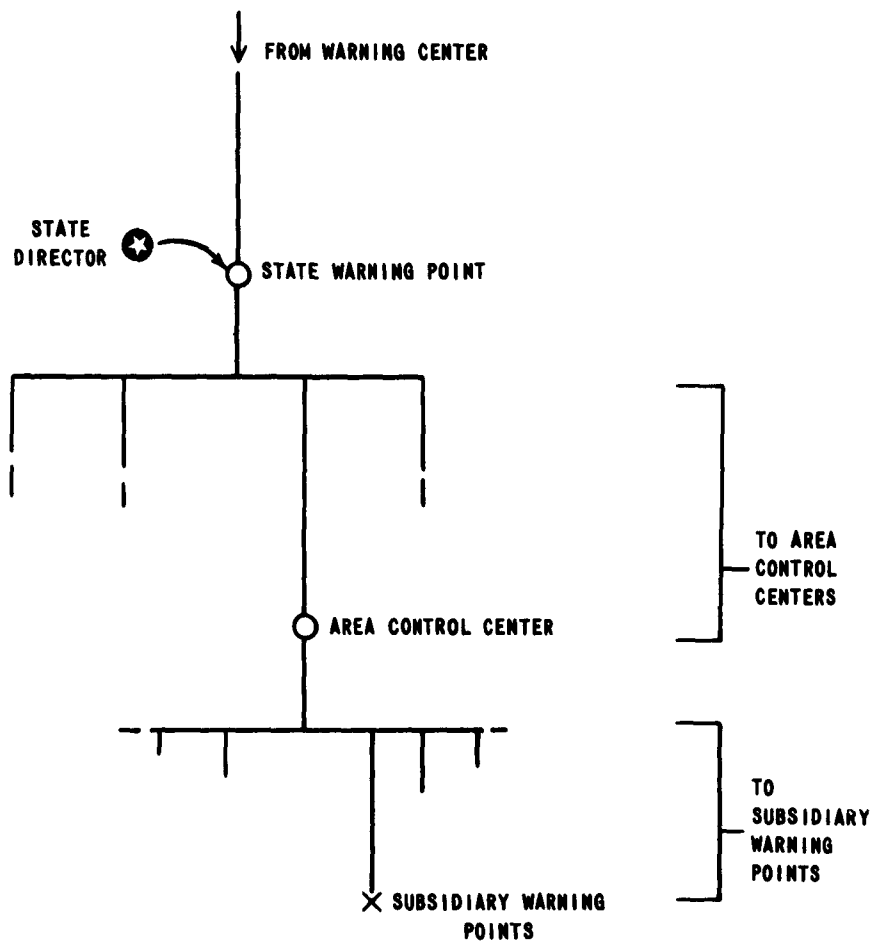
The decision rules (standing operating procedures) for the activation of the two accepted signals on the public action sirens are:

The State Warning Point orders the ALERT signal to be sounded in the three counties on the first warning that an attack is impending (strategic warning?). The public action sirens are then activated by a radio tone signal which emanates from the corresponding police troop headquarters in each county.

The State Warning Point orders the TAKE COVER signal to be sounded in the three counties upon receipt of information that attack is imminent. The police troop headquarters in each county activate the public action sirens.

The possible actions that should be taken upon the receipt of the warning signal are: civil defense personnel man their stations, key public officials proceed to their relocation sites, and general public make their last minute arrangements to occupy their shelters. The action and the TAKE COVER signal is that all personnel seek the best available shelter.

Even though no mention is made of this point in the 20 February 1962 Directive from the State, the 1958 Operational Survival Plan states that upon the sounding of the ALERT, the public must tune their radios on one of the CONELRAD frequencies. Presumably, then, this is the principal medium for the issuance of instructions or orders. Furthermore, the public is instructed not to use the telephone.



THE AREA CONTROL CENTER ACTIVATES ALL THE PUBLIC ACTION SIREMS IN THE AREA.

Figure 1-5 STATE OF DELAWARE ATTACK WARNING NETWORK

The only command level for attack-warning decisions appears to exist at the State Warning Point. It appears that the activation of the TAKE COVER signal is somewhat automatic under the conditions specified. That rule appears to be precisely stated. The decision regarding the activation of the ALERT signal appears to pose a more difficult problem to the State Director.

Figure I-5 illustrates the Delaware State Attack Warning Network.

C. The State of New Hampshire Attack-Warning Structure

The State of New Hampshire link in the attack-warning chain is depicted in Figure I-6. The state is divided into eight Civil Defense Areas (State of New Hampshire Operational Survival Plan - 1958). Five of these eight areas are referred to as "Reception Areas", and are assigned the responsibility of the reception and care for out-of-state evacuees. The remaining three Civil Defense Areas correspond to the Concord, Portsmouth, and Manchester Target Complexes and are designed to aid the respective targets in the event of a Civil Defense emergency.

Each of these areas is headed by an Area Civil Defense Coordinator who acts as a direct field representative of the State Civil Defense Agency. The State Civil Defense Director organizes and directs the Civil Defense operations for the state.

A local Civil Defense Director is placed in tactical control of emergency operations in the towns and cities of the state.

The New Hampshire Attack Warning Service is directed by the State Coordinator for Communications and Warning, who is also known as the State Attack Warning Officer.

The State Civil Defense Warning Point, which is manned by State Police personnel on a twenty-four hour schedule, is located at the New Hampshire State Police Headquarters at Concord. The state has a second Warning Point located in the Fire Station at Littleton, manned by the Littleton Firefighters, in the northern part of the state.

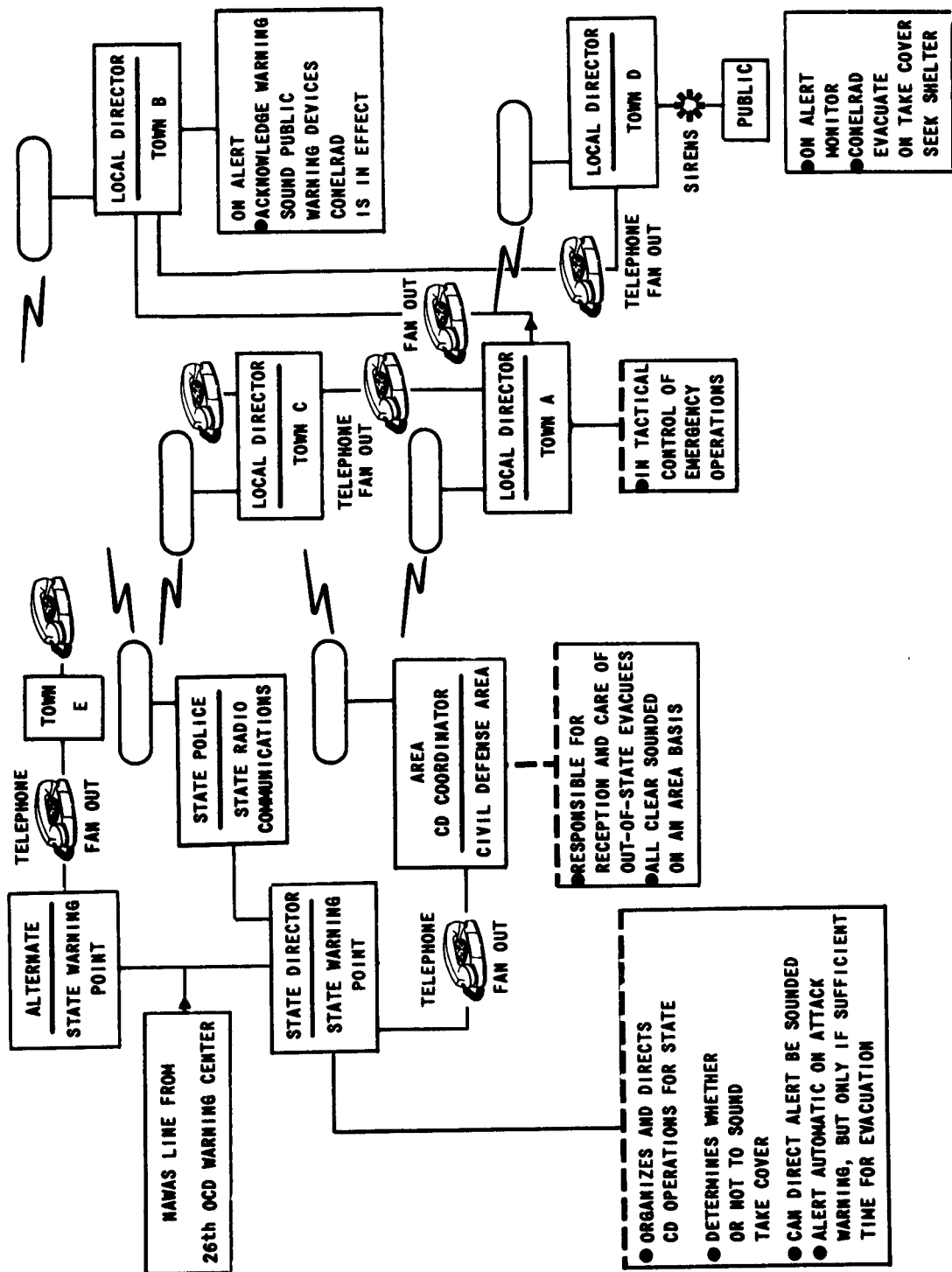


Figure 1-6 STATE OF NEW HAMPSHIRE LINK IN ATTACK WARNING CHAIN

The warning information is disseminated to the public, from the Warning Points by the New Hampshire State Radio-Communications system, and commercial telephone company networks. The telephone fan-out warning system is designed for point-to-point contact to all cities and towns in the state. Simultaneous warning is given via the State Police and other state radio-telephone networks. Should no contact be acknowledged by either of the aforementioned methods, a State Police Trooper, or other state officer operating in the immediate area, is dispatched to transmit the warning to the local authorities.

Emergency routing procedures are developed to replace commercial telephone circuits located in each of the three target complexes.

The state telephone fan-out network can be viewed as consisting of three echelons of calling points. The first calling point echelon constitutes the State Warning Point at Concord and the Warning Point at Littleton. The State Warning Point calls twelve stations (cities or towns); the Warning Point at Littleton calls nine stations. The stations called constitute the first echelon. In turn, each of the stations called by these two Warning Points calls a set of stations (this constitutes the second echelon). In turn, some of the stations called in this second echelon must call a set of stations (this constitutes the third and last echelon).

The order of calling the stations in the telephone fan-out network is not prescribed in the Operational Survival Plan.

Two types of warning are recognized in the state of New Hampshire: strategic warning and tactical warning. The definitions of the two correspond to those stated in the National Plan.

The attack warning system of New Hampshire does not incorporate any signal for notifying the public of strategic warning conditions. Upon the decision to declare a Strategic Warning Condition publicly, action is taken by the Attack Warning Service to disseminate this information as detailed under conditions of Tactical Warning (for the ALERT).

Tactical Warning is divided into two time phases: the ALERT and the TAKE COVER.

Immediately upon receiving an attack warning (other than strategic warning), via NAWAS, the State Civil Defense Warning Point in Concord and the Warning Point at Littleton transmits without further direction the ALERT attack warning, via the telephone and state radio-telephone networks. Upon the receipt of this warning, all public warning devices are sounded. CONELRAD is in effect. This warning can also be issued at the direction of the State Civil Defense Director.

However, the ALERT warning is disseminated only if there is considered to be sufficient time for evacuation.

The State Civil Defense Director, acting under the authority of the Governor, makes the determination as to whether the TAKE-COVER signal shall be sounded. If the State Director is not available, this authority is delegated to the Superintendent of State Police, and the State Attack Warning Officer. However, if the received information indicates that hostile aircraft are over any part of New England or its coastal waters, or within one-half hour flight time from New Hampshire, or that a strike in New England has actually occurred, then the operator on duty transmits the TAKE-COVER signal immediately.

Three warning signals are recognized in the state of New Hampshire: ALERT - a steady blast of 3 to 5 minutes, TAKE COVER - a wailing tone or short blasts for 3 minutes, ALL CLEAR - a steady blast of 30 seconds duration with 2 minutes of silence between blasts. The ALL-CLEAR signal is given by Areas only, rather than over the entire state. Actions to be taken upon receipt of warning: Upon the sounding of the ALERT signal, if there is determined to be a sufficient amount of time, the evacuation of the towns is implemented automatically, the public, at the same time, monitors the CONELRAD radio stations for supplementary Civil Defense instructions, upon the sounding of the TAKE COVER signal, the general public takes cover in the best available shelter. Key Civil Defense personnel man their preassigned posts.



The local communities, upon the receipt of an Attack Warning acknowledge the warning, and then notify the local Civil Defense Director. The public alarm systems is then sounded, as directed by the State Warning Point or Warning Point.

The reference cities for New Hampshire are Augusta, Maine, and Syracuse, New York.

It is understood that all communities are not adequately equipped with outdoor warning systems. Until standard equipment in sufficient quantity is available, local Civil Defense directors are to supplement existing equipment with mobile public address systems, local telephone fan-out circuits, etc. The basic signals are to be adhered to wherever possible.

Figure I-7 illustrates the attack warning fan-out network in the State of New Hampshire.

IV. TABULATION OF STATE ATTACK WARNING CHARACTERISTICS

The characteristics of the state attack warning structure are tabulated in Table I-1. As has been noted the TAKE COVER actions are relatively uniform; and the ALERT actions are generally varied. Most important to the Warning Decision Study, however, is the general lack of decision rules and criteria relating to (1) specifying the ALERT, and (2) specifying the actions to be taken following the ALERT.

TABLE 1-1
TABULATION OF STATE CHARACTERISTICS

CHARACTER	NEW YORK	DELAWARE	NEW HAMPSHIRE
COMMAND LEVEL	STATE TARGET SUPPORT AREA COUNTY	STATE	STATE AREA LOCAL
NO. OF COUNTIES	62	3	10
NO. OF CD AREAS	12	4	8
ATTACK WARNING DISSEMINATION (PRIMARY)	NAVAS EXTENSION	RADIO	TELEPHONE FAN-OUT
TYPES OF ALARMS	ALERT (INSTRUCTIONS FOLLOW) TAKE COVER	ALERT (NO EVACUATION) TAKE COVER	ALERT (EVACUATION ONLY) TAKE COVER ALL CLEAR
TYPES OF WARNING RECOGNIZED IN OSP	TACTICAL	ATTACK IMPENDING ATTACK IMMINENT	STRATEGIC TACTICAL
ALERT CRITERION	STATE DIRECTOR (UNSPECIFIED)	STATE DIRECTOR: ATTACK IMPENDING	STATE DIRECTOR, OR IMMEDIATELY ON RECEIPT OF ATTACK WARNING
ALERT ACTIONS	INSTRUCTIONS DISPERSAL OF MANPOWER, ETC. GO HOME	CD PERSONNEL MAN THEIR STATIONS KEY PUBLIC OFFICIALS PROCEED TO RELOCATION	EVACUATE TOWNS MONITOR CONELRAD
TAKE COVER CRITERION	STATE DIRECTOR, OR WHEN WARNING TIME IS 30 MINUTES OR LESS	ATTACK IMMINENT	STATE DIRECTOR, OR ONE-HALF HOUR FLIGHT TIME FROM N.H.: OR A STRIKE IN NEW ENGLAND HAS OCCURRED
TAKE COVER ACTIONS	SEEK SHELTER	SEEK SHELTER	KEY PERSONNEL MAN POSTS SEEK SHELTER

APPENDIX II - SCRIPT

ATTACK WARNING DISSEMINATION

SCRIPT

Attack-Warning Dissemination

Prologue

This script is based on an actual New York State exercise; and is extrapolated through the warning chain with the National Plan and the relevant state and county plans. It is probable that it will differ from the true situation in detail, but not, however, in substance. The purpose of such a script in a study of the character of AWAS is to call attention to points which did not escape the interest of the project investigators, such as:

(1) The sequence of acknowledgment warnings have no relationship to the losses that might occur if the target point goes unwarned. For example, why does the 25th Warning Center take precedence over the 26th; and later down the chain, Binghamton over the City of New York; etc.

(2) The information received by the Deputy Sheriff is extensive and in such form that he is (1) harried, (2) confused and (3) overburdened.

(3) The arrival of the Area Director, adding a decisive presence to Act III, does not of itself clarify the situation. Given the facts, however, he does know what to do.

ACT I

OCD National Warning Center, North American Air Defense Command to Warning Centers

(Place: OCD National Warning Center, Hq., North American Air Defense
Command, Ent Air Force Base, Colorado)

National Warning Officer: (declares Air Raid Warning, connects circuits, depresses ringing button for seven seconds, depresses warbler key for five seconds) "ATTENTION ALL STATIONS, EMERGENCY, THIS IS AN AIR RAID WARNING . . . REPEAT, THIS IS AN AIR RAID WARNING . . . ENEMY AIRCRAFT HAVE BEEN SIGHTED HEADING TOWARDS CONTINENTAL U.S. . . . STAND BY FOR WARNING TIMES . . . CENTERS ACKNOWLEDGE."

(Place: OCD 29th Warning Center; Hq., 33rd NORAD Region,
 Richards-Gebaur Air Force Base, Missouri)

29th Warning Officer: "29th Warning Center, Air Raid Warning"

(Place: OCD 25th Warning Center; Hq. 25th NORAD Region, McChord Air
 Force Base, Washington)

25th Warning Officer: "25th Warning Center, Air Raid Warning"

(Place: OCD 26th Warning Center; Hq 26th NORAD Region, Hancock Field,
 Syracuse, N. Y.)

26th Warning Officer: "26th Warning Center, Air Raid Warning"

(The roll call continues for OCD 28th Warning Center, Hq., 30th NORAD Region, Hamilton Air Force Base, California; OCD 30th Warning Center, Hq. 30th NORAD Region Truax Field, Madison, Wisconsin; OCD 32nd Warning Center, Hq. 32nd NORAD Region Oklahoma City Air Force Station, Oklahoma.)

ACT II

OCD Warning Centers to Warning Points, as
for example, the 26th Warning Center

(Place: OCD 26th Warning Center)

26th Warning Officer: "This is the 26th Warning Center. Warning times are not immediately available. Stand by for roll call . . . District of Columbia."

(Place: District of Columbia Warning Point, Classified Location)

D. C. Warning Officer: "District of Columbia Station, Air Raid Warning."

26th Warning Officer: "New York."

(Place: New York Warning Point, Albany, N. Y.)

N. Y. Warning Officer:

"New York Station. Repeat."

26th Warning Officer:

"This is the 26th Warning Center. Warning times are not immediately available.
Stand by for Roll call . . . Pennsylvania."

Pennsylvania Warning Officer:

"Pennsylvania Station. Air Raid Warning."

26th Warning Officer:

"New Jersey"

New Jersey Warning Officer:

"New Jersey Station . . . Air Raid Warning"

26th Warning Officer:

"Massachusetts"

Massachusetts Warning Officer:

"Massachusetts Station. Air Raid Warning".

26th Warning Officer:

"Virginia"

Virginia Warning Officer:

"Virginia Station. Air Raid Warning"

26th Warning Officer:

"Maryland"

Maryland Warning Officer:

"Maryland Station. Air Raid Warning"

26th Warning Officer:

"Connecticut"

Connecticut Warning Officer:

"Connecticut Station. Air Raid Warning"

26th Warning Officer:

"West Virginia"

West Virginia Warning Officer:

"West Virginia Station. Air Raid Warning"

26th Warning Officer:

"Maine"

Albany Warning Point:

"Albany, Air Raid Warning."

N. Y. State Warning Point:

"Roger, Albany . . . Binghamton"

Binghamton Warning Point:

"Binghamton, Air Raid Warning"

N. Y. State Warning Point:

"Roger, Binghamton . . . Buffalo"

Buffalo Warning Point:

"Buffalo Air Raid Warning"

Telephones Buffalo-Target Area Civil Defense Director, and attempts to contact other CD staff-members; requests and receives acknowledgments of warning from counties of Buffalo-Target Support Area (Chautauqua, Cattaraugus, Wyoming and Allegheny) connected to NAWAS line

N. Y. State Warning Point:

"Roger, Buffalo . . . Hawthorne"

Hawthorne Warning Point:

"Hawthorne, Air Raid Warning"

N. Y. State Warning Point:

"Roger, Hawthorne . . . Mineola"

Mineola Warning Point:

"Mineola, Air Raid Warning"

New York State Warning Point:

"Roger, Mineola . . . Newburgh"

Newburgh Warning Point:

"Newburgh, Air Raid Warning"

New York State Warning Point:

"Roger, Newburgh . . . New York"

New York City Warning Point:

"New York, Air Raid Warning"

New York State Warning Point:

"Roger, New York . . . Niagara Falls"

Niagara Falls Warning Point:

"Niagara Falls, Air Raid Warning"

New York State Warning Point:

"Roger, Niagara Falls . . . Plattsburgh"

Plattsburgh Warning Point:

"Plattsburgh, Air Raid Warning"

New York State Warning Point:

"Roger, Plattsburgh . . . Rochester"

Rochester Warning Point:

(No Answer)

New York State Warning Point:

"This is the New York State Warning Point. Stand by to acknowledge Air Raid Warning - Rochester". . . (No answer) . . . "Schenectady".

Schenectady Warning Point:

"Schenectady, Air Raid Warning"

New York State Warning Point:

"Roger, Schenectady . . . Syracuse."

Syracuse Warning Point:

"Syracuse, Air Raid Warning"

New York State Warning Point:

"Roger, Syracuse . . . Troy"

Troy Warning Point:

"Troy, Air Raid Warning"

New York State Warning Point:

"Roger, Troy . . . Utica"

Utica Warning Point:

"Utica, Air Raid Warning"

New York State Warning Point:

"Roger Utica . . . Rochester"

Rochester Warning Point:

(No answer)

(New York State Warning Point contacts Rochester by dialing an ordinary telephone, and informs Rochester of the Air Raid Warning.)

New York State Warning Point:

"This is the New York State Warning Point at Zero, Zero, Zero, Three, Zulu. The general location of the hostile aircraft is: over the North Atlantic Ocean, Atlantic Ocean off the coast of South Carolina, north to Massachusetts."

Buffalo Warning Point - (Deputy Sheriff interrupts his endeavors to telephone CD staff members, and now begins to record warning information.)

New York State Warning Point:

"Stand by for warning time to reference cities.

Augusta, Maine	35 minutes
Syracuse, New York	1 hour and 5 minutes
New York, N. Y.	50 minutes
Pittsburgh, Pa.	55 minutes
Washington, D. C.	45 minutes

. . . Raid Number FK77, location HJNM, time 0005 Zulu, course 240, speed 700, 100 fakers; raid number FK33, location HJGC, time 0005 Zulu course 320, speed 700, 80 fakers; raid no. FK 99, location HJEB, time 0005 Zulu, course 315, speed 700, 100 fakers . . . New York State Warning Point out at zero, zero, zero, six, Zulu . . . "

Buffalo Warning Point - (Deputy Sheriff interrupts his harried writing to attempt to continue his telephone contacts with other members of the Civil Defense Staff.)

New York State Warning Point:

"This is the New York State Warning Point; missile launchings have been detected from submarines in the North Atlantic Ocean off Greenland, and New Brunswick, and in the vicinity of Cuba. Warning time to reference cities is now 15 minutes. Missile track information; launch number H28, location JLHC . . . (continues). . .

Buffalo Warning Point Deputy Sheriff: (to himself) "Did he say fifteen minutes?" (Aloud - interrupts) "This is the Buffalo Warning Point. Did you say the warning time is now fifteen minutes?"

New York State Warning Point: ". . . launch Number A39, location JJHN, . . . time zero, zero, zero, seven, Zulu . . . course 275, speed 6000 . . . launch number B13 . . . (continues) . . ."

Buffalo Warning Point: (enter the Area Director)

Area Director: "What's happening?"

Deputy Sheriff: "I think he said the warning time to reference cities was fifteen minutes . . . "

Area Director: "Think?"

Deputy Sheriff: "I was recording information and contacting the staff at the time . . . If it was only fifteen minutes, wouldn't he order the TAKE COVER for the State?"

Area Director: "Maybe the State Director hasn't arrived there yet . . . Let's see your data . . . "

New York State Warning Point: ". . . Warning time to reference cities is now 13 minutes."

Area Director: "Sound the TAKE COVER!"

(BLACKOUT)

Epilogue

In the above situation, the decision presented is in the context of a stimulus-response situation, since for times of arrival less than one-half hour, it is mandatory that the TAKE COVER be sounded in New York State. On the other hand, if the choice of response is the choice of one from many possible responses, it is obvious that a careful evaluation of the input data would be required before an action would be initiated. Even in the most simple situations the form of the input data is in such form as to impede decision-making; and, clearly, this worsens as the situation becomes more complex.

The main point, then, is that data in its present undigested form* is inadequate to the task of influencing, expediting and activating decision-making at state and local level.

* see Recommended Research

PREFACE TO APPENDIX III

As has been pointed out in Sec. 1.2, methods that permit the earliest possible receipt of initial warning by a state, locality, and civilian population provide the opportunity to minimize losses.

The theory developed in the following appendix has potential applicability to the optimal dissemination of information within generically sequential networks (such as exist in the States of New York and New Hampshire).

The analysis relates the time available to perform survival actions by the civil population to the time expended in warning transmission and acknowledgment.

The practical application of the methods described must necessarily await the generation of loss functions* which accurately depict the expected time reactions of population centers in emergencies.

*See Recommend Research under Conclusions and Recommendations

APPENDIX III

AN OPTIMAL BASIS FOR ORDERING WARNING TIMES

by Norman P. Salz

APPENDIX III-A: ON MAXIMIZING THE MEAN TIME IN WHICH TO ACT

by Norman P. Salz

Consider a set of N populations n_1, n_2, \dots, n_N , and the time-of-arrival of the raid or missile to each is respectively, T_1, T_2, \dots, T_N . It is assumed that (a) warning is sequential¹ or (b) acknowledgment of warning receipt is sequential². The time remaining after receipt of the warning acknowledgment is the time-in-which-to-act. If acknowledgment of receipt of warning is not received from a population, an alternative warning route is activated; perhaps, the same route. Once again, the earlier in the sequence the population appears in the sequence, the sooner the warning/acknowledgment is received and the more time remaining in which to act. The problem to which this Appendix is addressed is as follows: In what sequence shall warnings be given and/or acknowledgments of warning accepted to provide the maximum mean time in which to act?

Assumptions

The times in which the warning/acknowledgment can be accomplished are ordered so that $t_1 \leq t_2 \leq t_3 \leq \dots \leq t_N$, where the subscript indicates the order.

Let us choose warning time t_{i_1} , in which to warn population n_1 ; t_{i_2} to warn population n_2 ; \dots ; t_{i_N} to warn population n_N ; where $t_{i_1}, t_{i_2}, \dots, t_{i_N}$ represents in some order the set t_1, t_2, \dots, t_N .

It is assumed with no loss of generality that the populations are ordered so that $n_1 \geq n_2 \geq n_3 \geq \dots \geq n_N$.

The Problem

The problem, then, is to maximize the mean time in which to act, τ_A , where

$$\tau_A = \frac{n_1(T_1 - t_{i_1}) + n_2(T_2 - t_{i_2}) + \dots + n_N(T_N - t_{i_N})}{M} \quad (1)$$

and $M = n_1 + n_2 + \dots + n_N$ = the total population; or to choose each t_{i_j} , $j = 1, 2, 3, \dots, N$ from the set $\{t_i\}$ to maximize τ_A .

¹For example, New Hampshire

²For example, New York

Solution

Observe that in (1) above n_i , T_i and M are constants. Hence, maximizing (1) is tantamount to minimizing the mean warning time,

$$\bar{t} = \frac{n_1 t_{i_1} + n_2 t_{i_2} + \dots + n_N t_{i_N}}{M} . \quad (2)$$

We shall first investigate the problem for two populations. (The M , a constant, may be ignored.)

Two Populations

Here one has $n_1 \geq n_2$ and $t_1 \leq t_2$. How shall the t 's be assigned to the n 's to minimize

$$n_1 t_{i_1} + n_2 t_{i_2} ?$$

There are only two possibilities; viz., either

$$n_1 t_1 + n_2 t_2 \text{ or } n_1 t_2 + n_2 t_1 .$$

We assert, and shall prove

$$n_1 t_1 + n_2 t_2 \leq n_1 t_2 + n_2 t_1$$

- Proof: 1) $n_2 \leq n_1$ by assumption
 $t_2 - t_1 \geq 0$ by assumption
- 2) Therefore $n_2(t_2 - t_1) \leq n_1(t_2 - t_1)$.
- 3) $n_1 t_1 + n_2 t_2 \leq n_2 t_1 + n_1 t_2 \quad 2 \in D$

Generalization

We assert now the theorem which we shall prove.

Given: $n_1 \geq n_2 \geq \dots \geq n_N$

$$t_1 \leq t_2 \leq \dots \leq t_N$$

Theorem: $n_1 t_1 + n_2 t_2 + \dots + n_N t_N \leq n_1 t_{i_1} + n_2 t_{i_2} + \dots + n_N t_{i_N}$

where t_{i_j} , $j = 1, 2, \dots, N$ is a unique element of the set $\{t_i\}$, $i = 1, 2, \dots, N$.

- Proof: 1) The theorem is shown to hold for $N = 2$.
- 2) Assume that the theorem holds for $N = k$; or that
- $$n_1 t_1 + n_2 t_2 + \dots + n_k t_k \leq n_1 t_{i_1} + \dots + n_k t_{i_k}$$

3) If we can show that the theorem holds for $N = k + 1$, the theorem is proved by the principle of finite induction.

4) Hence, to prove the theorem, we must show that

$$n_1 t_1 + n_2 t_2 + \dots + n_k t_k + n_{k+1} t_{k+1} \leq n_1 t_{i_1} + n_2 t_{i_2} + \dots + n_{k+1} t_{i_{k+1}}$$

5) Note that $t_{i_{k+1}}$ is either equal to t_{k+1} or it is not. Assume, for the moment, that $t_{i_{k+1}} = t_{k+1}$. But then the last term on the left side of the inequality is identical to the last term on the right. Hence, we can subtract from each side. But then the resulting expression holds, by the assumption that the theorem holds for $N = k$.

6) Now let us assume that $t_{i_{k+1}} \neq t_{k+1}$. Then t_{k+1} must appear in product on the right side with some n_i other than n_{k+1} , say n_r . The right member of the inequality then reads

$$\dots + n_r t_{k+1} + \dots + n_{k+1} t_{i_{k+1}}.$$

7) But $n_r \geq n_{k+1}$ and $t_{i_{k+1}} \leq t_{k+1}$ and so, since the theorem holds for $N = 2$, it follows that

$$n_r t_{i_{k+1}} + n_{k+1} t_{k+1} \leq n_r t_{k+1} + n_{k+1} t_{i_{k+1}}$$

8) It must also follow that an expression that is in all particulars identical to the right member of (4), or (6) except for the interchange of t_{k+1} with $t_{i_{k+1}}$ must be less than the right member; i.e.

$$\dots + n_r t_{i_{k+1}} + \dots + n_{k+1} t_{k+1} \leq \dots + n_r t_{k+1} + \dots + n_{k+1} t_{i_{k+1}}$$

9) But again, since the theorem holds for $N = k$, it follows also that

$$n_1 t_1 + n_2 t_2 + \dots + n_{k+1} t_{k+1} \leq \dots + n_r t_{i_{k+1}} + \dots + n_{k+1} t_{k+1},$$

for the $(k+1)$ terms are identical on both sides of the inequality.

10) By (8) and (9) it follows that

$$n_1 t_1 + n_2 t_2 + \dots + n_{k+1} t_{k+1} \leq n_1 t_{i_1} + n_2 t_{i_2} + \dots + n_{k+1} t_{i_{k+1}}$$

- 11) The theorem is proved to hold for $N = 2$; is assumed to hold for $N = k$; and is shown to hold for $N = k + 1$. Hence, the theorem is proved for all finite N .

Conclusion

The result arrived at herein may be stated as a principle:

In any sequential warning to, or acknowledgment by a set of populations, the maximum mean time in which to act - or equivalently, the minimum mean warning time - is obtained by warning the point of highest population first; next highest population, second; etc.

* * * * *

The following section is addressed to the warning problems introduced by reaction times of populations. Population-reaction is not instantaneous. Being warned and having 15 minutes in densely populated New York City is not equivalent to being warned and having 15 minutes in sparsely populated Chautauqua. The following develops a loss function that relates to population-reaction which is unique to each population center. The warning problem is then formulated in this context, and solved.

APPENDIX III-B: MINIMIZING LOSSES IN ATTACK WARNING ASSIGNMENT

by Norman P. Salz

Introduction

Consider a set of N warning points $(WP)_1, (WP)_2, \dots, (WP)_N$ and their associated populations $n'_1, n'_2, n'_3 \dots n'_N$. Assume that the respective time-of-arrival of the raid or missile to each population is $T_1, T_2, T_3 \dots T_N$. If the raid arrives over the population n'_i without warning, maximum losses of, say $\max (n'_i)$ is experienced if the raid arrives after adequate warning given to the population, minimum losses of say $\min (n'_i)$ is endured; and finally, if a belated warning is received, the warning time falls somewhere between the above extremes and the losses fall somewhere between minimum and maximum. What is implied by the foregoing is that there exists a time interval in which actions are taken after a warning is received; and that the length of the time interval influences the number of lives concerned. This time-interval may be called the build-up time of civil defense. This time interval, let us call it τ_i , commences on attack warning and terminates when either the weapon has detonated or when civil defense preparations are completed.

Figure III presents several different cases.

Figure III-a depicts the placid population in the absence of threat.

Figure III-b depicts the population n'_i under attack with τ_i minutes until the arrival of the raid. As shown, here the warning takes place early; i.e. there is sufficient time to permit the completion of the TAKE-COVER actions, and maximum (available) protection is provided.

Figure III-c depicts the attack as above, however, here the warning is received belatedly; i.e., there is inadequate time to provide maximum protection.

Figure III-d depicts the minimum number of survivors due to the complete absence of civil defense; i.e., there is no time remaining after warning in which to act.

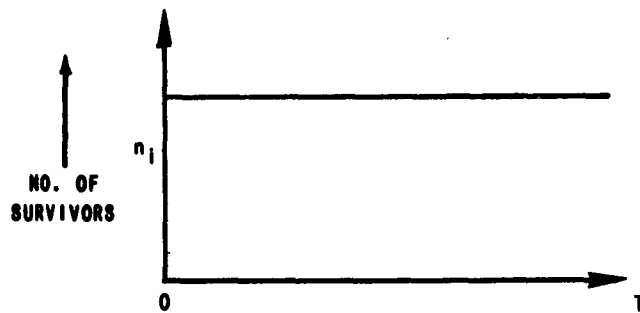


Figure III-1a NO THREAT

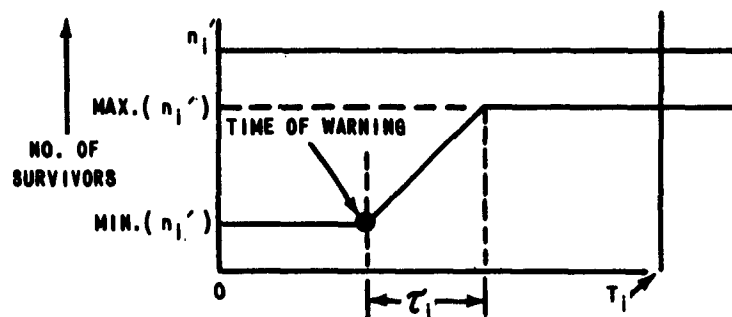


Figure III-1b TIME TO COMPLETE TAKE-COVER ACTION: EARLY WARNING

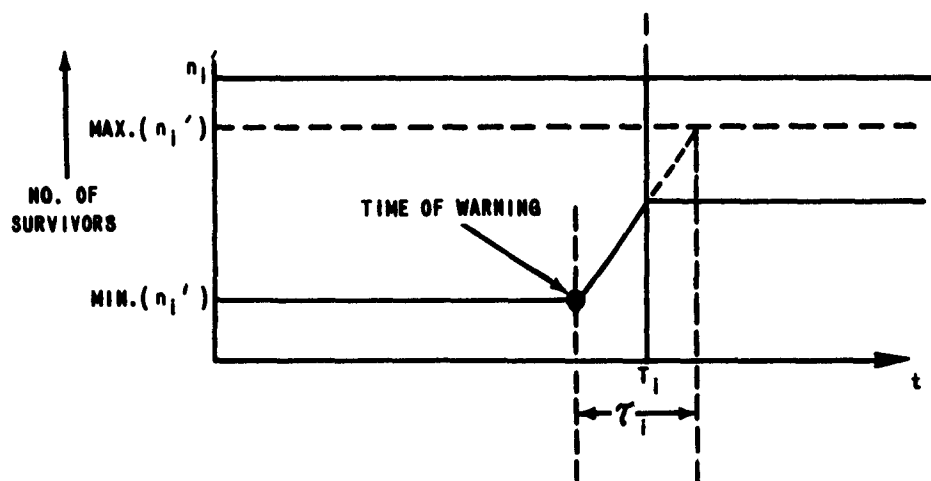


Figure III-1c BELATED WARNING: INADEQUATE TIME TO COMPLETE TAKE-COVER ACTION

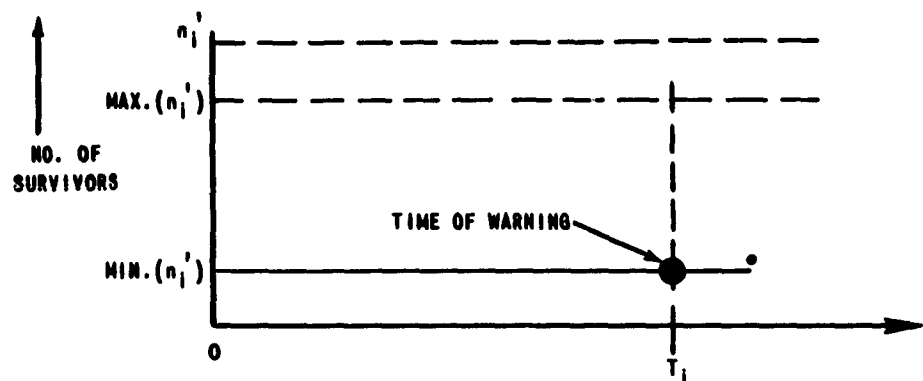


Figure III-1d LATE WARNING:NO CIVIL DEFENSE

As regards the above formulation, there are several points to be noted before proceeding to the problem statement:

1) The number of survivors during "build-up time" is represented as a linearly increasing function of time purely for illustrative purposes only. It is undoubtedly a nondecreasing function of time, in general. As to its exact mathematical form, an engineering guess* is $n = \min(n_i') + [\max(n_i') - \min(n_i')] (1 - e^{-t/\tau})$ where τ = reaction time-constant of population n_i' , and undoubtedly τ is a function of the number of people in n_i' , the discipline and training of population n_i' , the civil defense problem, the preplanning effectiveness, etc. (1)

2) Under any conditions of threat a minimum number survive; viz. $\min(n_i')$ survives population n_i' , $\min(n_2')$ survives population n_2' ,, $\min(n_N')$ survives population n_N' . Since these survivors are indifferent to the sequence in which warnings are given--the minimum number of survivors are regarded as zero survivors by subtracting each minimum respectively from the number of survivors, without loss of generality.

3) Under any conditions of threat the maximum number of survivors of n_i' is $\max(n_i')$. This is denoted as

$$\max(n_i') \equiv n_i' \quad (2)$$

*The author's

By reasoning similar to (2), the number of survivors needs only range from 0 to n_i where $i = 1, 2, 3, \dots, N$. Henceforth, the n_i is referred to as "populations" or "points".

The problem being considered may now be described as:

In what sequence should the N points be warned to ensure the maximum number of survivors?

Discussion

Loss Function

The respective number of survivors of the N points n_1, n_2, \dots, n_N is denoted by S_1, S_2, \dots, S_N . Then the total number surviving is clearly

$$S = S_1 + S_2 + \dots + S_N \quad (3)$$

$$\text{Now} \quad n_i = S_i + l_i, \quad i = 1, 2, \dots, N \quad (4)$$

where l_i = number of losses

Hence:

$$S = (n_1 - l_1) + (n_2 - l_2) + \dots + (n_N - l_N) \quad (5)$$

is the function that must be maximized. Since the total population

$$M = n_1 + n_2 + \dots + n_N \quad (6)$$

is constant, this is tantamount to minimizing the losses

$$L = l_1 + l_2 + \dots + l_N \quad (7)$$

Again referring to Figure III-1 a, b, c, d, it is seen that no (change of) losses occur unless the time of warning

$$t_w > T_i - \tau_i \quad (8)$$

and that following this time the losses increase to their maximum value.

Hence at $t_w \leq T_i - \tau_i$, losses are minimum

$T_i - \tau_i < t_w < T_i$, losses are between minimum
and maximum

$T_i < t_w$, losses are maximum

These results, encompassing all cases of the previous figure,
are presented in Figure III-2

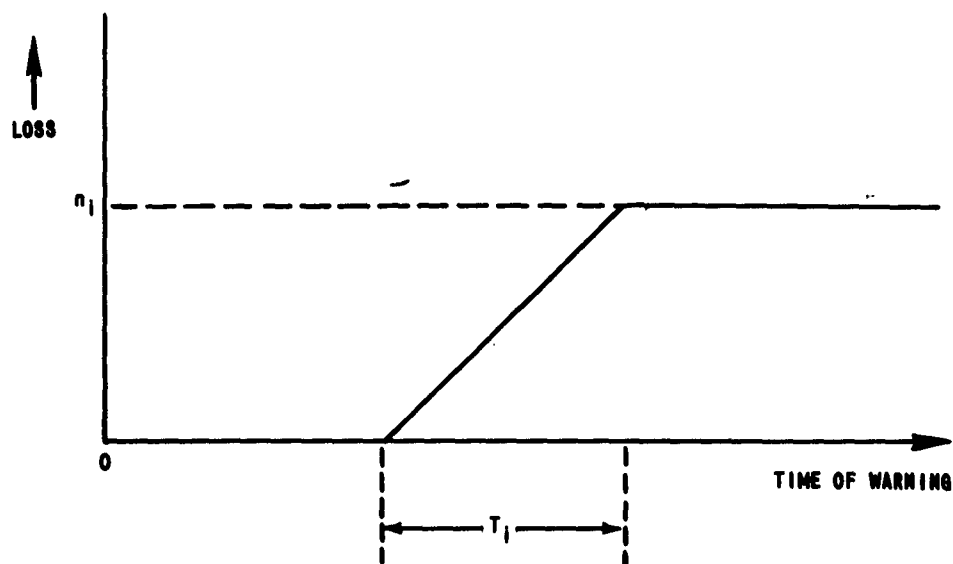


Figure III-2 LOSS FUNCTION

It is noted that the abscissa is now the time of warning, and that the resulting loss, although actually suffered at time T_i , is given directly as the ordinate corresponding to the time of warning.

Warning Times

We are concerned with a set of loss functions \mathcal{L}_i , where $i = 1, 2, \dots, N$ and we desire to determine the sequence in which warning is to take place to provide a sum of losses that is a minimum, as given by (7).

For the present, let it be further assumed that population n_i can be warned in time τ ; or alternately, population n_j can be warned in time τ ; where $i \neq j$ and $i, j = 1, 2, \dots, N$. Hence, the resulting times of warning is $\tau, 2\tau, \dots, N\tau$, which can be written as

$$\tau_j \equiv j\tau, \quad j = 1, 2, \dots, N \quad (9)$$

Example

By way of illustration, consider the problem for three populations. These produce the following possibilities

$$L_{min} = \min \left\{ \begin{array}{l} l_1(t_1) + l_2(t_2) + l_3(t_3), \text{ or} \\ l_1(t_1) + l_2(t_3) + l_3(t_2), \text{ or} \\ l_1(t_2) + l_2(t_1) + l_3(t_3), \text{ or} \\ l_1(t_2) + l_2(t_3) + l_3(t_1), \text{ or} \\ l_1(t_3) + l_2(t_1) + l_3(t_2), \text{ or} \\ l_1(t_3) + l_2(t_2) + l_3(t_1). \end{array} \right. \quad (10)$$

It is seen that these are merely representative of the six permutations of 1, 2, 3. For the case in point, a certain clarity is reached if a matrix representation is employed; viz.

	TIME t_1	TIME t_2	TIME t_3
l_1	l_{11}	l_{12}	l_{13}
l_2	l_{21}	l_{22}	l_{23}
l_3	l_{31}	l_{32}	l_{33}

(11)

where ℓ_{ij} describes the loss function corresponding to population i warned at time j . (12)

It is seen that population n , must be warned at time t_1 , t_2 , or t_3 and we must accept one of three losses, ℓ_{11} or ℓ_{12} or ℓ_{13} ; population n_2 must be warned at one of the remaining two times and accept the respective loss; population n_3 must be warned at the remaining time and the remaining loss accepted such that

$$L = \ell_{1j_1} + \ell_{2j_2} + \ell_{3j_3} \quad (13)$$

is a minimum where j_1, j_2, j_3 represent in some order 1, 2, 3.

Generalization

Given an $N \times N$ loss matrix (ℓ_{ij})

Problem: Determine the permutation j_1, j_2, \dots, j_N of the integers 1, 2, 3, ..., N such that

$$S = \ell_{1j_1} + \ell_{2j_2} + \dots + \ell_{Nj_N} \quad (14)$$

is a minimum.

Discussion

This problem has been solved.^{1, 2, 3} Computer routines exist⁴ for its solution. The following represents a variation of a technique developed to M. M. Flood,* which is tailored to the present application.

Given the loss matrix

$$L_1 = \begin{pmatrix} \ell_{11} & \ell_{12} & \dots & \ell_{1N} \\ \ell_{21} & \ell_{22} & \dots & \ell_{2N} \\ \vdots & & & \\ \ell_{N1} & \ell_{N2} & \dots & \ell_{NN} \end{pmatrix}$$

composed of non-negative elements.

Minimum Number of Lines Concept

1) If by any interchange of rows with rows and columns with columns, it is possible to create a main diagonal composed of zero elements alone,

* Reference 2

the problem is solved, since these zeros are chosen in their original positions of the L matrix and their sum S is (clearly zero) an absolute minimum for a sum of non-negative losses.

2) It is possible to determine whether or not this state (of independent zeros) is reached without performing the interchange, by a theorem due to Konig.*

The number of independent zeros of a matrix is equal to the minimum number of lines (rows and columns) that can be drawn through all the zero elements. The process of drawing lines through zero elements is referred to in this discussion as nulling out.

a) For example, consider the 4×4 matrix, where the x's denote respective loss values, not necessarily identical.

$$K_1 = \begin{pmatrix} \cancel{0} - \cancel{0} - \cancel{x} - \cancel{x} \\ \cancel{0} - x - \cancel{0} - \cancel{0} \\ \cancel{0} - \cancel{0} - \cancel{0} - \cancel{x} \\ \cancel{0} - x - \cancel{x} - \cancel{0} \end{pmatrix} = \begin{pmatrix} l_{11} & l_{12} & l_{13} & l_{14} \\ l_{21} & l_{22} & l_{23} & l_{24} \\ l_{31} & l_{32} & l_{33} & l_{34} \\ l_{41} & l_{42} & l_{43} & l_{44} \end{pmatrix}$$

The minimum number of lines that includes all the zero elements is 4. Thus, a solution is obtained.

b) On the other hand the 4×4 matrix

$$K_2 = \begin{pmatrix} 0 & x & x & 0 \\ 0 & x & x & 0 \\ 0 & x & x & 0 \\ 0 & x & x & 0 \end{pmatrix}$$

can be nulled out by 2 lines; no solution is obtained.

c) For a further example, consider the 4×4 matrix

$$K_3 = \begin{pmatrix} 0 & x & x & x \\ 0 & x & x & x \\ \cancel{0} - \cancel{0} - \cancel{0} - \cancel{0} \\ 0 & x & x & x \end{pmatrix}$$

It, too, is nulled out by only 2 lines and thus no solution is obtained.

Non-Uniqueness of Solution

Considering K_1 the minimum sum of losses is given by

$$l_{11} + l_{23} + l_{32} + l_{44}$$

or, by

$$l_{12} + l_{23} + l_{31} + l_{44} ,$$

* loc. cit.

and by other sequences, and these sums are identical in value, namely zero. Hence, if the sequence of warnings be n_1, n_3, n_2, n_4 or n_2, n_3, n_1, n_4 or whatever, the resulting sum is unchanged. In other words, the solution is not unique.

Definition of Equivalence

Two matrices A and B are said to be equivalent ($A \sim B$) if the solution of the assignment problem of matrix A is identical to the solution of the assignment problem of matrix B.

Extraction of Minimum Loss From System

In the event that all elements of the L matrix are nonzero then it is clear that, in the selection, some loss must be accepted. Now, denoting the minimum element of L as δ , clearly

$$L = \begin{pmatrix} l_{11} & \dots & l_{1N} \\ l_{21} & \dots & l_{2N} \\ \vdots & & \vdots \\ l_{N1} & \dots & l_{NN} \end{pmatrix} = \begin{pmatrix} l_{11} - \delta & \dots & l_{1N} - \delta \\ l_{21} - \delta & \dots & l_{2N} - \delta \\ \vdots & & \vdots \\ l_{N1} - \delta & \dots & l_{NN} - \delta \end{pmatrix} + \begin{pmatrix} \delta & \dots & \delta \\ \delta & \dots & \delta \\ \vdots & & \vdots \\ \delta & \dots & \delta \end{pmatrix}$$

Its interpretation as regards the present problem is as follows.

Making a choice of an element in L is equivalent to making the same choice in each of the two matrices of the right member, and adding.

But the last matrix by itself represents the addition of a loss, in the choice of an element from each row of

$$\delta + \delta + \dots + \delta = N\delta,$$

that is seen to be an intrinsic loss in the system, which must be accepted.

Let us write

$$L_1 = \begin{pmatrix} l_{11} - \delta & \dots & l_{1N} - \delta \\ l_{21} - \delta & \dots & l_{2N} - \delta \\ \vdots & & \vdots \\ l_{N1} - \delta & \dots & l_{NN} - \delta \end{pmatrix} \equiv \begin{pmatrix} l_{11}^{(1)} & \dots & l_{1N}^{(1)} \\ l_{21}^{(1)} & \dots & l_{2N}^{(1)} \\ \vdots & & \vdots \\ l_{N1}^{(1)} & \dots & l_{NN}^{(1)} \end{pmatrix}$$

It is thus clear that $L_1 \sim L$; hence, L_1 is considered.

If L_1 contains an independent set of N zeros, the solution is obtained; if not, we go on.

Extraction of Minimum Loss From Each Row

The L_1 matrix has at least one zero; all its other elements are non-negative. Choosing a zero element implies that the minimum loss thereunto appertaining is accepted. Now, other losses which must be accepted are identified.

Consider the elements of the i^{th} row, namely

$$l_{i1}^{(1)}, l_{i2}^{(1)}, l_{i3}^{(1)}, \dots, l_{iN}^{(1)}.$$

Since one of these elements must be chosen, a loss equal to the minimum loss of the i^{th} row is accepted, where $i = 1, 2, \dots, N$. Let $\delta_i^{(1)}$ be the minimum loss of the i^{th} row.

$$L_1 = \begin{pmatrix} l_{11}^{(1)} - \delta_1^{(1)} & l_{12}^{(1)} - \delta_1^{(1)} & \dots & l_{1N}^{(1)} - \delta_1^{(1)} \\ l_{21}^{(1)} - \delta_2^{(1)} & l_{22}^{(1)} - \delta_2^{(1)} & \dots & l_{2N}^{(1)} - \delta_2^{(1)} \\ l_{N1}^{(1)} - \delta_N^{(1)} & l_{N2}^{(1)} - \delta_N^{(1)} & \dots & l_{NN}^{(1)} - \delta_N^{(1)} \end{pmatrix} + \begin{pmatrix} \delta_1^{(1)} & \delta_1^{(1)} & \dots & \delta_1^{(1)} \\ \delta_2^{(1)} & \delta_2^{(1)} & \dots & \delta_2^{(1)} \\ \delta_N^{(1)} & \delta_N^{(1)} & \dots & \delta_N^{(1)} \end{pmatrix}$$

The first matrix of the right member is denoted by

$$L_2 = \begin{pmatrix} l_{11}^{(2)} & l_{12}^{(2)} & \dots & l_{1N}^{(2)} \\ l_{N1}^{(2)} & l_{N2}^{(2)} & \dots & l_{NN}^{(2)} \end{pmatrix}$$

By virtue of the foregoing discussion it follows that $L_1 \sim L_2$; and that it is concluded that the loss $\delta_1^{(1)} + \delta_2^{(1)} + \dots + \delta_N^{(1)}$ is accepted. If L_2 contains an independent set of N zeros, a solution is obtained; if not the process is continued.

Extraction of Minimum Loss From Each Column

The L_2 matrix contains at least one zero in each row, and all its other elements are non-negative. Choosing a zero implies that the minimum loss associated with the choice is accepted. Other losses are now identified

which must be accepted.

Consider the elements of the column, namely

$$l_{1j}^{(2)}, l_{2j}^{(2)}, l_{3j}, \dots, l_{Nj}^{(2)}$$

Since one of these elements must be chosen, a loss equal to the minimum loss of the j^{th} column $j = 1, 2, \dots, N$ must be accepted.

Let $\delta_j^{(2)}$ be the minimum loss of the j^{th} column.

$$L_2 = \begin{pmatrix} l_{11} - \delta_1^{(2)} & l_{12} - \delta_2^{(2)} & \dots & l_{1N} - \delta_N^{(2)} \\ l_{21} - \delta_1^{(2)} & l_{22} - \delta_2^{(2)} & \dots & l_{2N} - \delta_N^{(2)} \\ \vdots & \vdots & \ddots & \vdots \\ l_{N1} - \delta_1^{(2)} & l_{N2} - \delta_2^{(2)} & \dots & l_{NN} - \delta_N^{(2)} \end{pmatrix} + \begin{pmatrix} \delta_1^{(2)} & \delta_2^{(2)} & \dots & \delta_N^{(2)} \\ \delta_1^{(2)} & \delta_2^{(2)} & \dots & \delta_N^{(2)} \\ \vdots & \vdots & \ddots & \vdots \\ \delta_1^{(2)} & \delta_2^{(2)} & \dots & \delta_N^{(2)} \end{pmatrix}$$

The first matrix of the right member is denoted by

$$L_3 = \begin{pmatrix} l_{11}^{(3)} & l_{12}^{(3)} & \dots & l_{1N}^{(3)} \\ \vdots & \vdots & \ddots & \vdots \\ l_{N1}^{(3)} & l_{N2}^{(3)} & \dots & l_{NN}^{(3)} \end{pmatrix}$$

By virtue of the above discussion, it is clear that $L_2 \sim L_3$ and that it is concluded that the loss $\delta_1^{(2)} + \delta_2^{(2)} + \dots + \delta_N^{(2)}$ must be accepted.

If L_3 contains an independent set of N zeros, the solution is achieved; if not go on.

Further Considerations

What has been verified, by the foregoing is the truth of the three theorems.

Theorem I - Given $L = (l_{ij})$. Then $L \sim L'$
 where $L' = (l_{ij} + a)$ and a is an arbitrary constant.

This asserts that a fixed loss can be added to every element of the matrix to provide an equivalent problem matrix.

Theorem II - Given $L = (l_{ij})$. Then $L \sim L'$
 where $L' = (l_{ij} + a_i)$ and a_i is an arbitrary constant for rows
 $i = 1, 2, \dots, N$.

This asserts that a row loss a_i , $i = 1, \dots, N$ can be added to the elements of the respective rows of the matrix to provide an equivalent problem matrix.

Theorem III - Given $L = (l_{ij})$. Then $L \sim L'$
 where $L' = (l_{ij} + a_j)$, and a_j is an arbitrary constant
 for columns $j = 1, 2, \dots, N$.

This asserts that a column loss a_j , $j = 1, 2, \dots, N$ can be added to the elements of the respective columns of the matrix to provide an equivalent problem matrix.

* * *

Consider the set of elements S_N nulled out by the minimum set of lines in matrix L_j , and define the remaining set of elements to be the set S . Assume the number of independent zeros of the set S_N are less than N . Assume further, for the moment, that row-row and column-column interchanges have placed a set of zeros on the main diagonal. The resulting matrix L'_j might then appear, as shown in Figure III-3 for illustration.

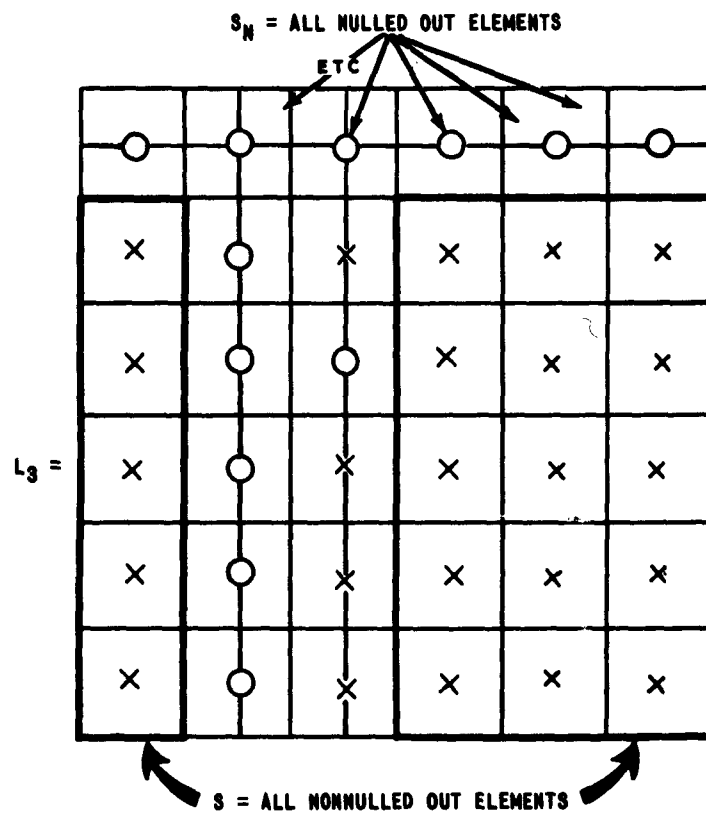


Figure III-3 6 x 6 MATRIX 3 INDEPENDENT ZEROS

Since the number of independent zeros is at present incomplete, the minimum loss provided by set S is accepted.

1) Let the minimum element of $S = \delta$, and subtract δ from each element of L_3 to produce a resulting matrix, L_4 . By theorem I, $L_4 \sim L_3$.

By doing this, at least one new zero in the set S has been created. Unfortunately, in the process, all zeros of S_N have been converted into $-\delta$.

2) Add a matrix to L_4 consisting of a loss of $+\delta$ to each element of each row of S_N , and of zero to each element of S . Thus,

$$L_5 = L_4 + \begin{pmatrix} \delta & \delta & \delta & \delta & \delta & \delta \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

By Theorem II, $L_5 \sim L_4$.

In the process the elements of S are left unchanged, and restored all zeros, which were marred by step (1).

3) Add a matrix to L_5 consisting of a loss of $+\delta$ to each element of each column of S_N , and of zero to each element. Thus,

$$L_6 = L_5 + \begin{pmatrix} 0 & \delta & \delta & 0 & 0 & 0 \\ 0 & \delta & \delta & 0 & 0 & 0 \\ 0 & \delta & \delta & 0 & 0 & 0 \\ 0 & \delta & \delta & 0 & 0 & 0 \\ 0 & \delta & \delta & 0 & 0 & 0 \end{pmatrix}$$

By Theorem III, $L_6 \sim L_5$

In the process the elements of S are left unchanged.

The net result of steps 1, 2 and 3 is to subtract δ from S and to add to the elements at the points of intersection of the minimal lines.

Since a new matrix of non-negative elements $L_6 \sim L_4$ is created by the process, L_6 is examined to see if it possesses a set of N independent zeros. If it does, the solution is obtained. If not, a new set S'_N is created of nulled out elements and S' of non-nulled out elements, and proceed as above.

Summary of Method

At each step determine whether or not the number of independent zeros is N by (equivalently) determining the minimum number of lines passing through all zero elements. If at any step the minimum number is less than N we proceed to the next step.

- 1) Subtract from each element of the matrix the minimum element of the matrix.
- 2) Subtract from each row the minimum element of each row
- 3) Subtract from each column the minimum element of each column.
- 4) Call the nulled out elements S_N ; the non-nulled out elements S . Determine δ the minimum element of S . Subtract δ from each element of S ; add δ to each element at the intersection point of the minimal lines.
- 5) Repeat step (4).

Unsolved Assignment Problem

In connection with warning assignment, there is an unsolved problem,* which is stated for the record.

Given a set of populations n_1, n_2, \dots, n_N with respective loss functions $l_1(t), l_2(t), \dots, l_N(t)$ and times-of-arrival of raid T_1, T_2, \dots, T_N . If the time interval to warn n_1 is τ_1 , to warn n_2 is τ_2, \dots, n_N is τ_N , how should the warnings be sequenced to provide minimum loss of life?

*It is solvable by enumeration

Example

Let $N = 3$

Possibilities

	<u>Sequences</u>
$l_1(\tau_1) + l_2(\tau_1 + \tau_2) + l_3(\tau_1 + \tau_2 + \tau_3),$	1, 2, 3
$l_1(\tau_1) + l_2(\tau_1 + \tau_2 + \tau_3) + l_3(\tau_1 + \tau_3),$	1, 3, 2
$l_1(\tau_1 + \tau_2) + l_2(\tau_2) + l_3(\tau_1 + \tau_2 + \tau_3),$	2, 1, 3
$l_1(\tau_1 + \tau_2 + \tau_3) + l_2(\tau_2) + l_3(\tau_2 + \tau_3),$	2, 3, 1
$l_1(\tau_1 + \tau_3) + l_2(\tau_1 + \tau_2 + \tau_3) l_3(\tau_3),$	3, 1, 2
$l_1(\tau_1 + \tau_2 + \tau_3) + l_2(\tau_2 + \tau_3) l_3(\tau_3)$	3, 2, 1

References

- 1) Dwyer, P.S., "The Solution of the Hitchcock Transportation Problem with a Method of Reduced Matrices" Statistical Laboratory, University of Michigan, December 1955 (privately circulated).
- 2) Flood, M.M., "The Traveling-Salesman Problem," J. Opns. Res. Soc. Am., 4, no. 1, 6175 (February 1956).
- 3) Kuhn, H.W., "The Hungarian Method for the Assignment Problem," Nav. Res. Log. Quart. 2, nos. 1 and 2 83-98 (March-June 1955)
- 4) Hodges, J.H., "Analysis of the Hungarian Method," Cornell Aeronautical Laboratory, Inc., 24 July 1960.

APPENDIX III-C: OPTIMUM WARNING STRUCTURE CONSIDERATIONS

by Norman P. Salz

Introduction

The warning structure is to some extent sequential, viz., A warns B who in turn warns C, etc. In the instance of New Hampshire, for example, a warning point warns a second warning point which warns a third, while the first warns a fourth, etc. In this Appendix the following problem is examined.

What constitutes an optimal structure to produce minimum loss of life?

Assumption

It is assumed that the time it takes to warn a warning point is equal to the time it takes to warn any other warning point. (The result of this is a productive answer to the question. This assumption may be relaxed at a future engagement with the problem).

Structure

First consider the problem of structure, where it is assumed that a single point has a time interval of τ available to it. In this time the point can issue a single warning to a second warning point, as shown in Figure III-4.



Figure III-4

Now assume that the initial point has a time interval of 2τ available. In this time the initial point can warn two points; and the first point warned can warn an additional point in the time available to it, as shown in Figure III-5.

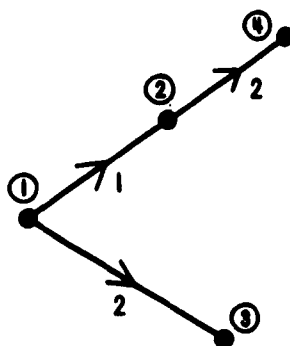


Figure III-5

Now assume that a time interval of 3τ is available to a single point. The structure is as shown in Figure III-6.

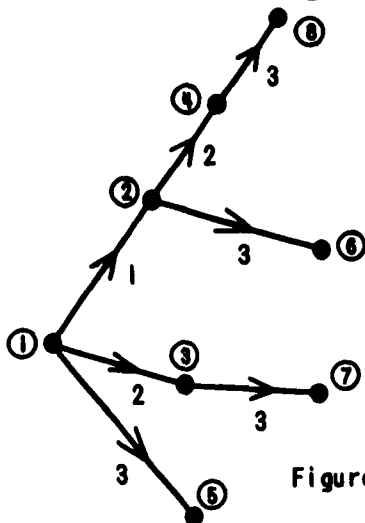


Figure III -6

As shown, in the first time interval

WP #1 warns WP #2

In the second time interval

WP #1 warns WP #3

and

WP #2 warns WP #4

In the third time interval

WP #1 warns WP #5
 WP #2 warns WP #6
 WP #3 warns WP #7
 WP #4 warns WP #8

An optimal structure is provided within the restrictions of the problem.

Generalization

It is clear that the solution can be readily generalized on the foregoing. If the time available to a warning point is zero, clearly this point is the only one warned. Hence, the following may be tabulated

<u>Time Available</u>	<u>Total # of Points Warned</u>
0	1
τ	2
2τ	4
3τ	8

and it follows directly with time $n\tau$ available that

$$\text{Total Number points warned} = 2^{n\tau} \quad (1)$$

Further, if the points warned during the same time interval are enclosed by brackets (), it is seen that in sequential time intervals 1, 2, 3, ..., the new points warned are, respectively.

$(WP_2), (WP_3, WP_4), (WP_5, WP_6, WP_7, WP_8), \dots$

Problem

The structure problem may now be formulated.

Given: A set of N warning points WP_1, WP_2, \dots, WP_N relating to the populations n_1, n_2, \dots, n_N .

The times $\tau, 2\tau, 3\tau, \dots$ at which the respective number of new points warned are 1, 2, 4, ...

The times of arrival of raid to each respective warning point T_1, T_2, \dots, T_N and,

The respective loss functions $l_1(t), l_2(t), \dots, l_N(t)$.

What should the warning structure be to provide minimum loss of life?

Solution

This problem is readily solved. Let us assume that the order in which to warn 7 warning points is at issue. The following matrix is formed and then solve directly as a Warning Assignment problem, as discussed in Appendix III-B.

	τ	2τ	2τ	3τ	3τ	3τ	3τ
$l_1 \rightarrow$	l_{11}	l_{12}	l_{12}	l_{13}	l_{13}	l_{13}	l_{13}
$l_2 \rightarrow$	l_{21}	l_{22}	l_{22}	l_{23}	l_{23}	l_{23}	l_{23}
$l_3 \rightarrow$	l_{31}	l_{32}	l_{32}	l_{33}	l_{33}	l_{33}	l_{33}
$l_4 \rightarrow$	l_{41}	l_{42}	l_{42}	l_{43}	l_{43}	l_{43}	l_{43}
$l_5 \rightarrow$	l_{51}	l_{52}	l_{52}	l_{53}	l_{53}	l_{53}	l_{53}
$l_6 \rightarrow$	l_{61}	l_{62}	l_{62}	l_{63}	l_{63}	l_{63}	l_{63}
$l_7 \rightarrow$	l_{71}	l_{72}	l_{72}	l_{73}	l_{73}	l_{73}	l_{73}